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TECHNOLOGY REVIEW

February 1951

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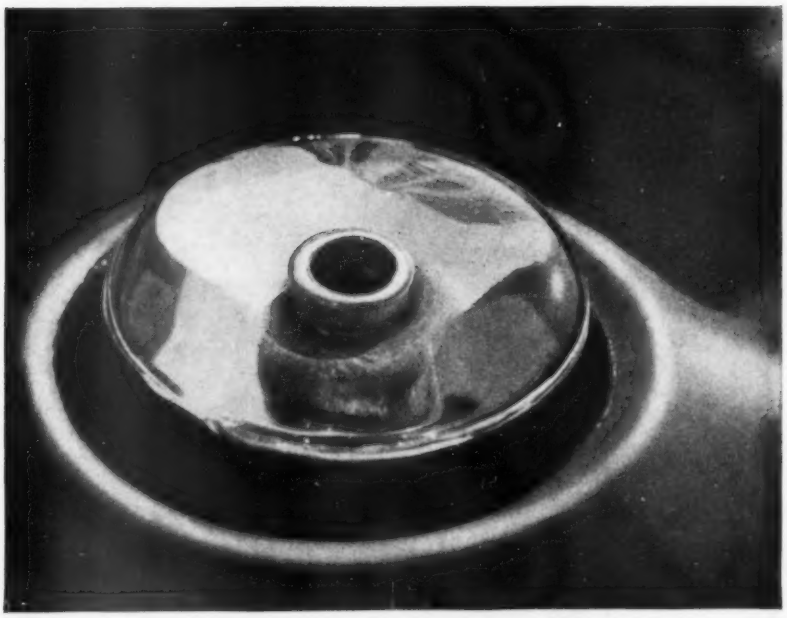

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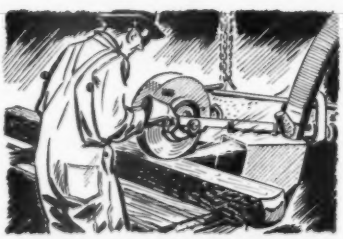

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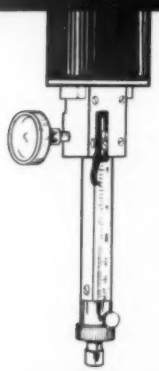

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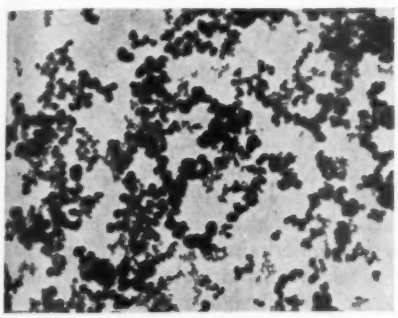

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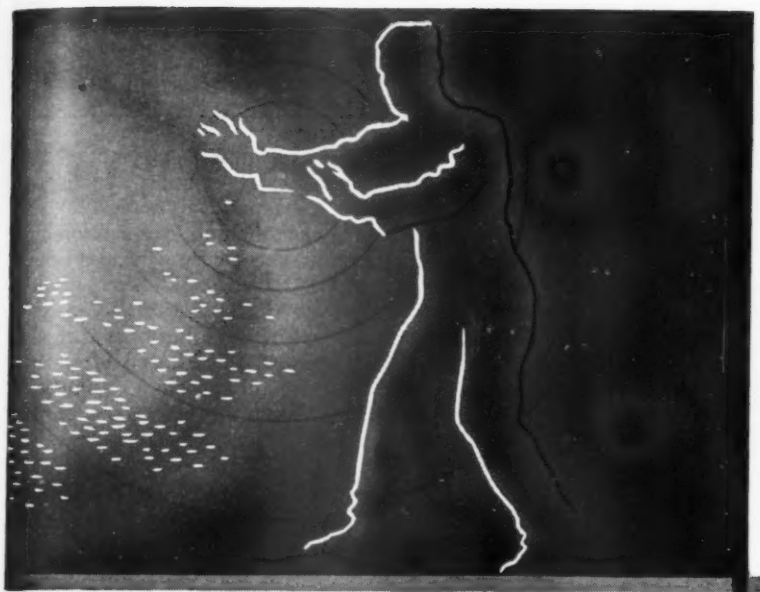
THE TABULAR VIEW

Science in Administration. — Normally we do not expect administrators, as such, to make significant contributions to science or morality, nor do we assume that our religious leaders possess unusual competence in science or administration. Yet, not infrequently are scientists berated for failing to assume active administrative leadership in applying the fruits of science to the advancement of man's moral virtue. Perhaps the scientist should be flattered that his abilities are sometimes regarded as universal – if not superhuman. But those trained in science can hardly be expected to perform outstanding service in fields which, too often, require an unscientific temperament, as PROFESSOR PHILIP M. MORSE of the Department of Physics at M.I.T., points out (page 191). Dr. Morse holds that the same progress which has been achieved by operations research in the conduct of warfare (for which this comparatively new study was originally developed) can be expected to result when operations research is applied to the peacetime administration of industry. Professor Morse speaks with particular authority on this subject, for, as research director and deputy director of the Weapons Evaluation Group of the National Military Establishment in World War II, he was chief scientific authority for the agency conducting operations research for the Joint Chiefs of Staff and the Secretary of Defense. He was also one of the originators, and the first director, of the Brookhaven National Laboratory of the Atomic Energy Commission.

Success in Individuals. — In the upheaval of uncertainty which surrounds many a young person – and older ones as well – it is perhaps well to be reminded of the basic function of education in a democratic society. In "Education for Freedom" (page 195), PROFESSOR JOSEPH H. KEENAN, '22, of the Department of Mechanical Engineering, emphasizes the point that a requirement for self-government among men is a reasonably high degree of development of the intellectual and moral potentialities of the individual. Following his graduation from the Institute in 1922, Professor Keenan became engineer for the General Electric Company until 1928 when he became assistant professor of mechanical engineering at Stevens Institute of Technology. In 1934 he returned to M.I.T. as associate professor of mechanical engineering, and in 1939 was promoted to a full professorship. Professor Keenan has taken deep interest in international affairs, and, for the next term, will be on leave of absence under a Fulbright grant to study in England, as recorded in the November, 1950, issue of The Technology Review.

Safety in Automobiles. — A proper practical understanding of the forces, energies, and acceleration of moving vehicles will do much to reduce automobile accidents. Greater attention to design for safety and a willingness to forego some of the elements of sleek, fashionable appearance, will have a similar effect,

(*Concluded on page 182*)



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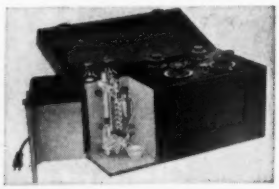

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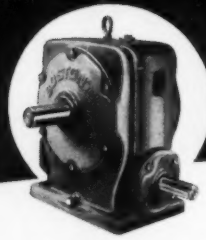

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THE TABULAR VIEW

(Concluded from page 180)

even for those who have never been exposed to a course in the dynamics of rigid bodies. In fact, as DAVID O. WOODBURY, '21, reminds us (page 196), suitable co-operation between the public and automobile manufacturers, perhaps backed by a proper educational campaign, can do much to minimize casualties on the road. A graduate of the Institute's Course in Electrical Engineering, Mr. Woodbury has turned to literary channels and, since 1929 has been a free-lance interpreter of science. Something like a dozen books are to his credit, in addition to many magazine and newspaper articles on the significance of science and engineering.

Sojourn in Avesta. — Last summer five recent graduates of Technology had the unusual opportunity and good fortune to be selected to carry on engineering research in industrial plants and research organizations, all within a radius of approximately 100 miles of Avesta, in Sweden.

Based on reports written by Jacques A. F. Hill, '47, Richard M. Schotland, '48, and Robert N. Randall, '50, "Study in Sweden" (page 197) records the benefits of expanded horizons which are inevitably the result of rubbing elbows with colleagues in another country. Now back at M.I.T., Mr. Hill is continuing research in aeronautics at the Supersonic Wind Tunnel, and Mr. Schotland is engaged in research and advanced study in the Department of Meterology. Mr. Randall's visit was extended to a full year, and he is still engaged in metallurgical research in Sweden. The reports from these three graduates come to The Review through the consideration of Norman D. Padelford who is professor of international relations in the M.I.T. Department of Economics and Social Science, and chairman of the Foreign Study Committee.

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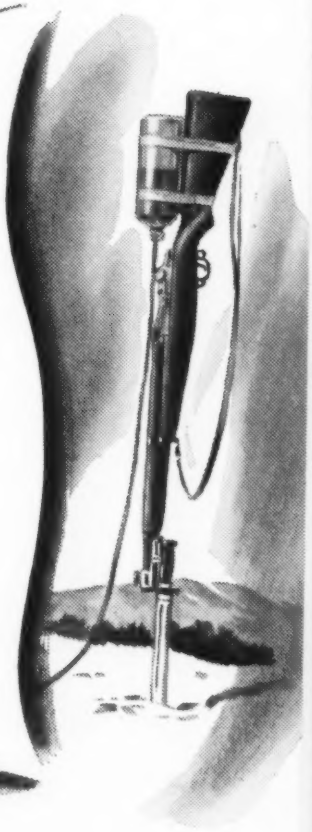

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Ward Allan Howe

Who mentioned politics?

THE TECHNOLOGY REVIEW

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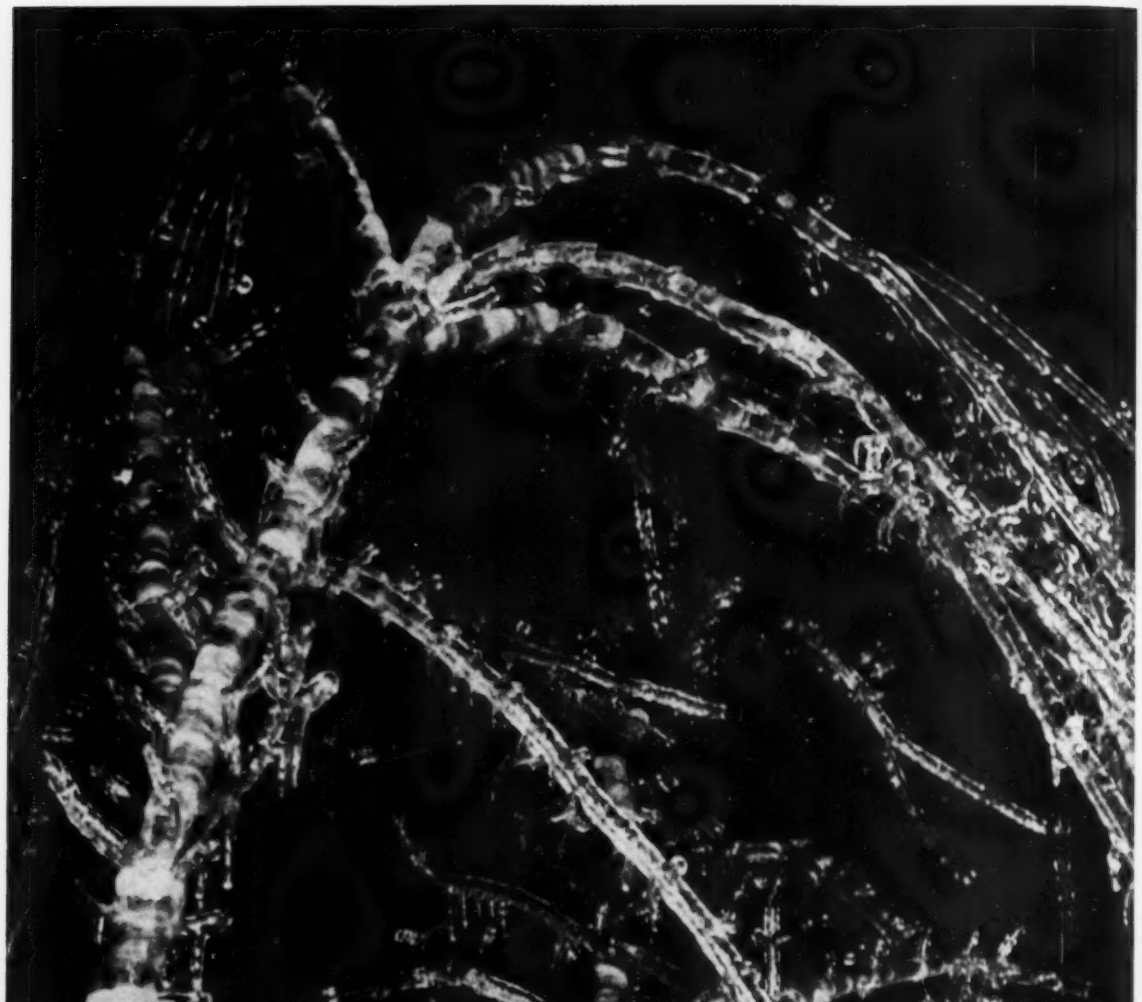


Robert H. Smyth, '28

Ice Tree

THE
TECHNOLOGY
REVIEW

Vol. 53, No. 4 February, 1951

The Trend of Affairs

Imitating Nature

EMIL FISCHER, the pioneer organic chemist (1852–1919), said that his two paramount ambitions were to make a lump of sugar and to lay an egg. Thus he neatly epitomized the difficulties faced by chemists seeking to assemble, in the laboratory, the complex molecules of naturally occurring substances. Fischer approached achievement of the first of his two aspirations, as he did succeed in synthesizing a number of sugars. If he were alive today, he would have witnessed total accomplishment of the first of his goals, as sucrose (the sugar that is made in lumps and found in sugar bowls) has now been made synthetically.

In the making of an egg, Fischer could scarcely have aspired to generating the spark of life that resides in the egg. In reproducing the chemical ingredients of an egg, Fischer progressed part of the way toward the making of proteins. For he made peptides (protein building blocks that in size fall between the elementary amino acids and the complete complex protein molecules) that closely simulated the natural substances. The protein molecule, as found in nature, has not been synthesized even today, despite the great strides in synthetic organic chemistry since Fischer's time.

The single fact that the protein molecule has not been synthesized provides one useful index of the current status of the synthetic reproduction of biological substances. Thus, none of the enzymes can yet be made synthetically, as enzymes are protein in constitution. Hormones of a protein nature, such as insulin, have not been synthesized; whereas sex hormones, which are steroids, are now made synthetically. Vitamins are not protein in constitution; and with the exception of vitamin D most of the vitamins have been successfully synthesized. In this connection it is noteworthy that vitamin A, the predominant vitamin of Fischer's egg, has been synthesized in recent years and has now reached the phase of large-scale commercial production.

The synthetic reproduction of complex natural molecules has profound importance, both academic and practical. At the outset, such synthesis is necessary to establish categorically molecular constitution and arrangement. Furthermore, synthesis is an indispensable preliminary step in metabolism studies using tracer elements. In such studies, compounds are tagged, or labeled, by introducing heavy or radioactive elements into their molecule. Then such tagged compounds are fed or otherwise administered to experimental animals, and the metabolic fate of the compound within the animal is followed by analyzing tissues, secretions, or excretions for the presence of the tagged element. It has not been possible to introduce tagged elements into the molecules of natural substances; instead, labeled compounds have been made only through synthesis, using the tagged element where it fits into the molecule.

Finally, the synthesis of useful natural compounds is a prime practical objective because in this way abundant production in pure form, and at relatively low cost, is made possible. The vast quantity of synthetic vitamins manufactured today is but one example of this point. In view of these exigencies, continued progress in the synthetic reproduction of complex natural molecules is as diligently pursued by present-day organic chemists as it was earlier by Emil Fischer.

Speed to Burn

AT low velocities, the surface temperature of objects moving through the air is not noticeably increased. But at sea level, the temperature of a wing surface may rise 100 degrees F. for speeds of 500 miles per hour; whereas the temperature increase may be something like 3,000 degrees F. for speeds of 5,000

miles per hour. Very high speed projectiles may, therefore, easily acquire speeds to burn – or melt – and must be designed to take account of high temperatures and high-temperature gradients. It becomes clear that before very high speed flight can be accomplished, we must know more about the physical conditions to be encountered by missiles.

A study to determine some of the thermal and stress conditions encountered in high-speed flight has been completed at M.I.T. as a joint undertaking of the Department of Aeronautical Engineering, under the supervision of Professor Joseph S. Newell, '19, and Professor Hsue-Shen Tsien, '36, former member of the Department, and of the Department of Mechanical Engineering, under the direction of Joseph Kaye, '34, Associate Professor of Mechanical Engineering, and Warren M. Rohsenow, Assistant Professor of Mechanical Engineering. The work, which was performed for the United States Air Force, was undertaken to determine what happens to a thin, wedge-shaped wing moving at high supersonic speeds – corresponding to Mach numbers between 1 and 6, or speeds between approximately 740 and 4,450 miles per hour.

The results obtained in the solution of this particular problem may be summarized as follows:

1. The most severe temperature rise will occur at the leading and trailing edges of the wedge-shaped wing. In fact, when the wing attains a Mach number of 6, the temperature of the leading and trailing edges is just slightly below the melting point of steel, namely, 2,300 degrees F. The temperature rise of points located along the chord of this wing will have risen to only about 100 degrees above the initial value when the Mach number of 6 is first reached.

2. At the time the Mach number of 6 is first reached, the temperature along the four surfaces of the wedge-shaped wing will decrease from 2,300 degrees F. at the leading edge to about 700 degrees F. at the center of the wing; it will then rise along the aft portion of the wing, reaching a value of 2,300 degrees F. at the trailing edge.

3. The temperature gradients along the vertical planes in the wing will be exceedingly large, of the order of 2,000 to 10,000 degrees F. per foot. On the other hand, the temperature gradient along horizontal planes in the wing, parallel to the chord, will be considerably smaller, of the order of 200 degrees to 2,000 degrees F. per foot.

4. The presence of these large inequalities of temperature in the wing structure will give rise to large thermal stresses. In fact, calculations based on elastic theory show that the maximum stress could reach a value of 400,000 pounds per square inch, if the material remained in the elastic region.

This study has shown that a large amount of experimental work must be carried out in the field of supersonic heat transfer before one can safely design a device to fly for long periods at speeds greater than 1,400 miles per hour. The study also indicates the range of thermal stresses, temperatures, temperature gradients, and secondary aerodynamic stresses which may be encountered in any experimental study and thereby indicates the laboratory facilities required for a further continuation of this important work on an experimental basis.

From Theory to Practice

NOISE of such magnitude as to have serious effect on fundamental research at the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics at Cleveland, has been housed, harnessed, and cut down to a whisper. The transition from stentorian stampede to soothing silence was accomplished with an important contribution from an M.I.T. doctoral thesis on acoustic theory.

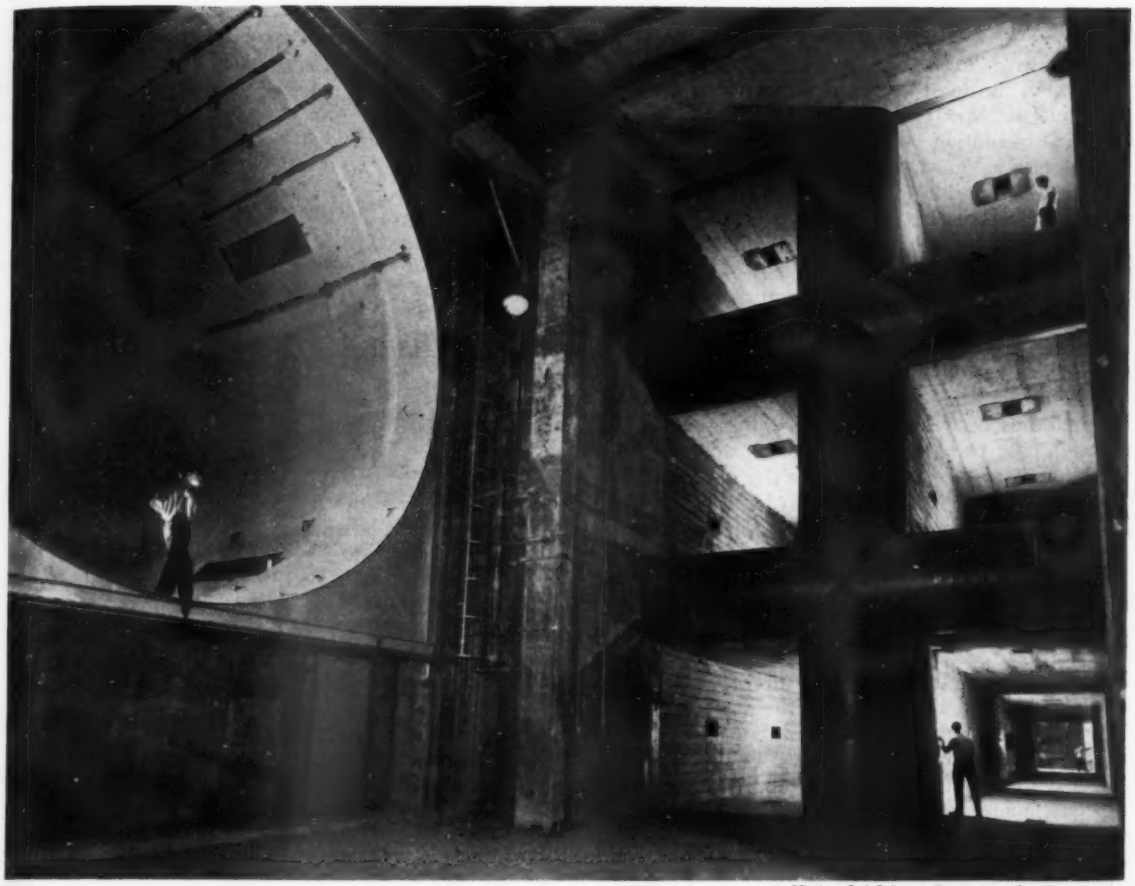
When a ram-jet engine was put through test runs at supersonic speed conditions in the eight- by six-foot supersonic wind tunnel, tremendous disturbances in the extremely low-frequency ranges were generated. These came from energy generated by the wind tunnel's 87,000-horsepower compressor, which sent shock waves and enormous quantities of turbulent air pounding against the tunnel walls and from combustion noise from the burning ram-jet operating in the tunnel test section. The acoustic treatment of the supersonic wind tunnel was originally designed on the basis of the best acoustical information then available, but the data did not prove adequate to muffle the noise which developed when ram-jet engines were put on test.

The conditions created in the tunnel caused a sound output of extremely high intensity, in the range of from five to 100 cycles per second. The lower range of such frequencies produces pressure waves through the atmosphere which cannot be heard by the human ear but are of such intensity as to vibrate the walls of structures at considerable distances, sufficient to rattle windows, doors, and dishes.

Conventional types of acoustical treatment do not absorb sounds of such low frequencies, although they are effective in attenuating the human voice, office noises, and similar sounds for which most of the energy occurs at frequencies of a few hundred cycles per second. Obviously, special acoustical designs were needed to dissipate the very low-frequency sound, and to provide adequate control of the noise contemplated in a wide range of research projects.

The problem was solved by a consulting group headed by M.I.T. staff members Richard H. Bolt and Leo L. Beranek, director and technical director, respectively, of the Acoustics Laboratory, Robert B. Newman, '49, and Samuel Labate, '48. A new type of tuned absorptive duct was proposed by Professor Beranek, based on a theory contributed by Professor Philip M. Morse, of the Department of Physics, a few years ago. But no theory was available for engineering at the very lowest frequencies. At this point, the new knowledge applicable to this problem, and developed in the Acoustics Laboratory in connection with the doctoral thesis of K. Uno Ingård, '50, was put to use. The new results made it possible, for the first time, to calculate noise-reducing properties of acoustic resonators accurately at very low frequencies.

To attenuate noise of the lower frequencies, new construction was required, consisting of a series of properly designed resonators, both inside the existing concrete housing of the 230-foot long, trumpetlike, subsonic diffuser, and also in the planned addition to the acoustical house. Concrete partitions were built at five stations inside the diffuser housing. By taking into



National Advisory Committee for Aeronautics

Intake end, showing six passages and arrangement of the Helmholtz resonators for the attenuation of noise, particularly of very low frequency, at the supersonic wind tunnel of the Lewis Flight Propulsion Laboratory in Cleveland. The discharge end of the subsonic diffuser is at the left.

consideration the diameter of the diffuser in each of the chambers, it was possible to cut slots in the diffuser at each station, of such size as to match the air volume of each chamber, thus producing a resonator to attenuate effectively within its design frequency range. The research studies and tests which were made had previously indicated that it was feasible to attenuate the lower frequencies first, dissipating the higher frequencies as progress was made downstream.

The illustration on the cover of this issue shows an upstream view from the discharge end of the subsonic diffuser, with placement of Helmholtz resonator parts for the frequency range of from five to 11 cycles.

Fluorine Chemistry

At present, a small segment of the chemical industry, that branch of chemistry dealing with compounds of fluorine, may soon be destined, through rapid expansion, to play a significant role in chemical manufacturing. The possibility of applying inert, stable fluorides in industry in such widely different applications as lubrication, refrigeration, and high-voltage electrical insulation, is one underlying reason for this anticipated growth. Another is that recent progress in fluorine chemistry has disclosed methods of safely transporting reactive compounds of fluorine – a highly active gas in the elementary state – which may be used in place of the element, thereby stimulating and reducing the cost of research in chemistry.

Such, at least, are some of the possibilities which are being studied in the Department of Chemistry at M.I.T. by a research group working under the direction of Professor Walter C. Schumb, of the Department.

The remarkable group of compounds of carbon and fluorine comprising the fluorocarbons, for example, possess the valuable properties of resistance to powerful oxidizing agents, physical stability at high temperatures, and lack of inflammability, making them valuable for such purposes as lubrication under high-temperature conditions and other similar critical applications. Aside from the desirable properties enumerated above, the fluorocarbons have physical properties otherwise resembling those of the hydrocarbons, which they could replace in certain chemical reactions. Up to the present, the fluorocarbons have been expensive, directly or indirectly requiring elementary fluorine for their preparation; and, since not produced on a relatively large scale, they were not extensively used. But efforts are being made to produce such compounds at reasonable costs on a commercial scale.

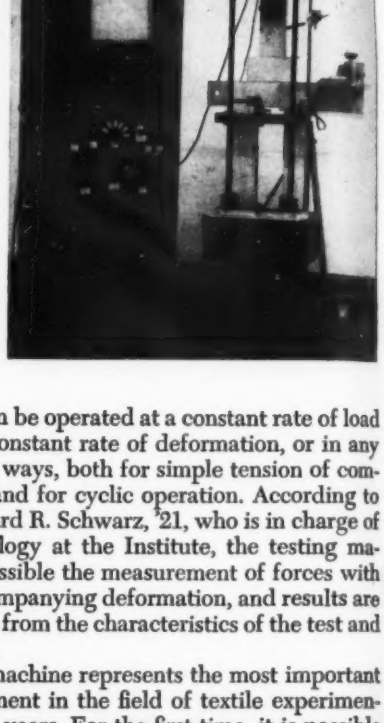
Certain of the chlorofluorides of carbon, including the group of compounds familiarly known by the trade name of "Freon," have long been utilized as refrigerants. The most common of this group, dichlorodifluoromethane (CCl_2F_2), has also been used as an electrical insulating gas in such equipment as high-voltage generators. Other volatile fluorides, notably sulphur hexafluoride (SF_6), have been employed for the same purpose. Under most conditions, this compound is a remarkably inert, nitrogenlike gas, and is probably the best known gaseous high-voltage insulator. Its use in high-voltage apparatus, such as x-ray generators, where its insulating properties are most appreciated, is accompanied by some decomposition into lower fluorides of sulphur and elementary fluorine, with resulting danger of corrosive attack on the materials of which electrical equipment is constructed. The program of inorganic research in the Department of Chemistry, under the supervision of Professor Schumb, is directed toward establishing first, the exact composition and nature of the lower fluorides of sulphur, some of which have not been definitely established; and second, the possibility of reconditioning the gas while in use, either by absorption of the contaminating decomposition products, or possibly by reconverting these decomposition products back to the stable sulphur hexafluoride. If this program should prove feasible, the utilization of the otherwise superior insulating properties of sulphur hexafluoride would be greatly facilitated.

The synthesis of fluorocarbons and other fluorides is usually achieved by the use of elementary fluorine, which is highly reactive and noxious. Attention has been given, therefore, to improved methods of preparing, storing, and handling fluorine gas, especially under pressure. Relatively small cylinders of this highly reactive compressed gas are commercially available, but are expensive and require careful handling with adequate safety precautions. Study of fluorine chemistry gives ample indication that, for many purposes, certain of the halogen fluorides can be used as fluorine substitutes for research and manufacturing, and such compounds can be transported more safely and inexpensively.

Along somewhat more academic lines, the preparation and study of various other metal and nonmetal fluorides has been proceeding, together with the establishment of the structures of such compounds by infrared and Raman spectroscopic methods. Richard C. Lord, Associate Professor of Chemistry and Director of the Institute's Spectroscopy Laboratory, has collaborated in the determination of these structures.

Suit Yourself

An important new type of servocontrolled testing machine for the precise measurement of stress and deformation in plastics, as well as in fibers, yarns, and fabrics, is in operation at the Institute's Samuel Slater Memorial Research Laboratory. Better suits and other clothing may be expected to emerge through the use of the new tester, since the forces acting on the fibers under test are measured and recorded by means of electronic circuits; and effects of friction, inertia, and momentum are eliminated in the measurement.



The M.I.T. servocontrolled testing machine, with recorder shown at the left. The transducer load cell is near top of right-hand rack, and servocontrol mechanism is at center. The machine is used for studying fiber properties not previously investigated for lack of suitable equipment.

The tester can be operated at a constant rate of load application, a constant rate of deformation, or in any combination of ways, both for simple tension of compression tests, and for cyclic operation. According to Professor Edward R. Schwarz, '21, who is in charge of Textile Technology at the Institute, the testing machine makes possible the measurement of forces with or without accompanying deformation, and results are completely free from the characteristics of the test and measuring unit.

The testing machine represents the most important single development in the field of textile experimentation in recent years. For the first time, it is possible to determine certain important fundamental properties of natural and synthetic fibers. A knowledge of the properties of fibers opens the way for the production of new textile materials; it also paves the way for more intelligent use of existing fabrics by blending of fibers to meet prescribed characteristics. Thus, the way is opened for the textile scientist to engineer fabrics to meet specified requirements – a feat which has never before been possible in textiles, except in exceedingly limited degree.

Important results are expected to come from the use of the textile testing device, which was developed to promote and advance the effectiveness of instruction and research at M.I.T. For example, when a specimen is allowed to recover partially after some load (short of that needed to produce failure) has been applied, and the resulting deformation is then maintained constant, the load increases for a certain length of time in a manner characteristic of the material and its past history. This phenomenon has not been studied in the past, but is now the subject of research using the servocontrolled tester.

The present model of the testing machine uses a new form of energy converter, or transducer, developed by Kurt S. Lion, Associate Professor of Applied Biophysics. Contributions to the development of the machine have also been made by the Servomechanisms Laboratory under the direction of Professor Gordon S. Brown, '31, and by the Plastics Research Laboratory staff under the direction of Professor Albert G. H. Dietz, '32, of the Department of Building Engineering and Construction at Technology.

Operations Research

Science Cannot Take Over the Task of Administration, but Policy Decisions Can Be Made More Wisely by Scientific Study of Administrative Problems through Operations Research

By PHILIP M. MORSE

Some of the most interesting new developments in applied science encompass the study of human activity rather than of the physical sciences. One sees instances of this in many research projects already in progress at M.I.T.; further confirmation of the trend is indicated in the recent establishment of the School of Industrial Management. Utilizing these new developments, in addition to the many traditional tools of science, the burgeoning field of operations research has as its goal the direct study of administrative problems. The aim is not to supplant the administrator, but to help him make his decisions more wisely and effectively.

Operations research began during World War II; its early successes were chiefly in the field of military operations where it is still of utmost importance. Since the war, it has been applied in business and industry, and is well on its way to becoming a recognized field of applied science. A professional society serving the new field has been established in England; in the United States, the National Research Council has a Committee on Operations Research; a graduate course in the subject has been offered at M.I.T. for the last two years.

At present, the chief handicap to its further development is the great shortage of trained men. In the present emergency, the military services alone could use many times the number now available; and there is industry's interest in persons with training in operations research. The Institute is aware of these needs and is contributing in many ways to meet the demand. In addition to the course offered, it serves the Navy. The official Navy operations research group is called the Operations Evaluation Group. It is a team of civilian scientists headed by Jacinto Steinhardt, housed in The Pentagon as a part of the staff of the Chief of Naval Operations, supplied by M.I.T. on a contract through the Division of Industrial Coöperation. Beyond this, a number of research projects being conducted at the Institute are providing new tools for application to operations research.

One of these projects, for example, concerns the theory of communication, which is being studied intensively in the M.I.T. Department of Electrical Engineering. The immediate practical applications, in the field of electrical communication, are interesting enough. But they are trivial compared to the possibilities for future application; as, for example, in the field of language. How much redundancy must there be in a language in order that the meaning to be imparted will survive lapses in attention of the listener? A radar operator sees the screen he is supposed to be watching less than half the time, according to wartime data; all of us must really receive but a fraction of the words we hear or read. Things must be said twice and three times to have a good chance of transmission from mind to mind. Natural languages have this necessary redundancy built into them. If we should ever need to devise a universal language for a single world, considerations of this sort will be quite necessary, and communication theory should play a central role in the design stages.

The experiments of Alexander Bavelas, '48, Associate Professor of Psychology at Technology, on the transmission of ideas and orders in task-oriented groups point the way to other applications of communications theory. Professor Bavelas restricts the channels of communication between members of the group to some specified pattern, and then observes group action as the members try to solve some co-operative task. Some of the action, the nature and number of the person-to-person messages sent, the emergence of leadership in the group, and the frequency of failures, for example, show a definite correlation with the nature of the prescribed communication net. As yet, the experiments have not developed to a stage where any but the most rudimentary analysis is required, but a combination of communication theory and topology will probably be needed to unravel further extension of the work to larger groups or more complex tasks. The implications of such studies with regard to our understanding of social dynamics are, of course, great.

Another field of mathematics which is pointed to human affairs is the theory of games, recently developed by John Von Neumann at the Institute for Advanced Study, Princeton, N.J. Here is the beginning of a quantitative analysis of competition, of bluff and counterbluff, which is a part of war and business, as well as poker. Thus far, the serious applications of the theory have been in military studies, but some applications to business dynamics are now under way.

Most of these newly developed mathematical tools, and many other more familiar ones, are being used intensively in operations research. This field of application of science takes, as its subject of study, the operations of an organization. Whereas the civil engineer uses mathematics and physics in designing or strengthening a bridge, the operations research

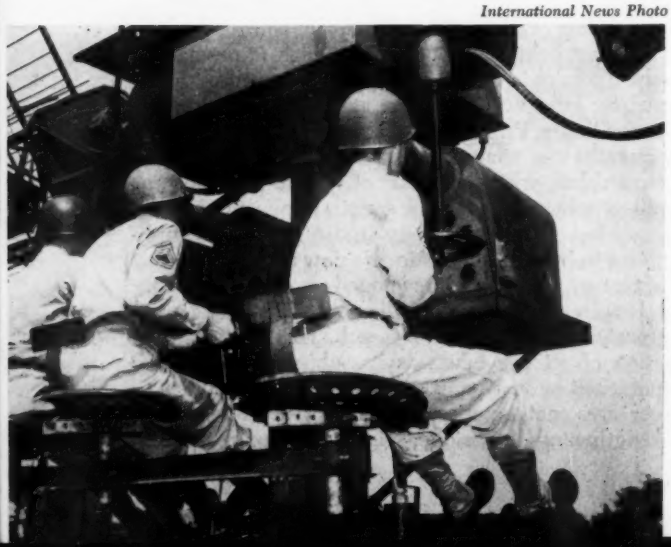
worker uses mathematics and other sciences to study and improve the interactions in an organization of men and equipment while it is performing some cooperative task. The civil engineer reports to, and works closely with, the builder of the bridge; the operations research worker reports to, and works closely with, the administrator, the executive officer in charge of the operation.

Operations research has been defined as "a scientific method of providing executive departments with a quantitative basis for decisions regarding operations under their control." Some of its techniques have been used sporadically in industrial and military problems earlier; but its inception, as a recognized and organized activity amenable of application to a variety of problems, occurred at the beginning of World War II. Its value is well recognized in military organizations, and each branch of our services now has its own operations research group as part of its staff. Since the war, an increasing number of applications have been made in business and industry where its value has also been amply demonstrated.

Perhaps a more philosophical definition might also be attempted. Science and the scientific method have often been criticized for making possible the production of machines and weapons and then failing to show how these products are wisely or effectively used. In a rather fundamental sense, however, this criticism involves a contradiction in terms. Science and scientific techniques are not designed to make decisions or to carry on the basic operations of administration, such as running an army or a business. They have been designed to increase our understanding about some facet of nature; and while this increased understanding will make the task of some administrator wider in scope, or will enable him to make his decisions more wisely, or will reveal to him more fully the consequences of his decisions, it seldom will make the decision for him. The administrative decisions concerning the use of the products of science should be based on all the data available, but they nearly always involve other factors of politics, morale, or personalities, which are non-scientific and which must be decided in an arbitrary sort of way. In many cases, it is more important *that* a decision be made than *how* it is made, which, of course, represents a thoroughly unscientific attitude.

In radar, and radar countermeasure, sometimes the too early application of a countermeasure is as harmful as one too late. Reports must be properly evaluated to decide on an action which will be truly effective.

International News Photo



Science Is Not Administration

But, if science cannot and should not take over the task of administering the use of the equipment it makes possible, it can nevertheless assist in an important way in the running of the operations of civilization – in the use of the equipment it helped create. It can provide this assistance only by being itself; by studying operations and understanding them quantitatively and impersonally, rather than by administering them. Here the subject for study is the operation itself: the traffic on a highway, the operation of strategic bombing, the routing of busses or freight cars, or the tactics of sinking a submarine. Just as physical and chemical nature is studied to provide facts which may be used to build an aircraft, so the operations of strategic bombing have uniformities and trends which, when understood, may be used to improve operations and to redesign them under changing circumstances. Here, again, the scientist does not usurp the job of the administrator who is running the operation. He seeks to understand the operation more clearly so that his clearer picture, when transmitted to the executive, will enable this officer to make his decisions more wisely and effectively.

It will be objected that the scientific study of the operations of civilization is the task of the social scientists, and that physical scientists should stick to their lasts, turning out more gadgets. This objection was successfully refuted during the last war by the experience of the operations research groups working with the various branches of the services. These mixed groups included mathematicians and physical and biological scientists, as well as social scientists (and even lawyers!); they studied various operations of war in a scientific manner, in close collaboration with the operations officer responsible for making the decisions concerning the operation. The groups worked out a quantitative picture of the tactics of sinking a submarine, for example, or of bombing a city; showed how the results depended on the equipment involved and on the way the equipment was used; and presented this picture to the operations officer so he could issue his orders wisely and use his forces as effectively as possible. These groups worked out a possible symbiosis of scientist and administrator which, evidently, has very great possibilities for further uses in other less destructive aspects of the operations of civilization.

It was found that physical scientists and mathematicians were at least as necessary, for an effective group, as were the social scientists. Nearly all the operations studied had aspects which were familiar to the physical scientist and which he was trained to analyze. The biologist and psychologist were necessary, of course; but most groups were not effective without representation from all the scientific disciplines. The writer is convinced that many aspects of economics and other social sciences will not advance appreciably until they are subjected to the techniques familiar to the physical scientist.

It should be emphasized again that operations research is not merely statistics, efficiency engineering, or market analysis. For one thing, it utilizes the technique so successful in physics and other sciences, of the interplay between tentative theory and experimental test – of a trial conceptual model and a systematic testing of its consequences. In a recent study of a nationwide sales problem, it was necessary to set up a mathematical model of the customer – not just the average customer, but of all customers with all their variability and their tendencies to change from year to year – before a satisfactory theory could be devised and the problem solved. Detailed mathematical analysis showed that a relatively few sampling runs would be needed to obtain the important parameters, and that the earlier market surveys, despite their complexity and detail, had failed to measure some of the most important quantities. Once these parameters were obtained, it was possible to answer such questions as: Should additional sales effort be spent trying to sell the best customers more, trying to win back past customers, or trying to capture new markets? Only by the use of conceptual models of an operation, checked by experiment, can questions of such nature be answered; mere correlation of data, blindly taken, cannot suffice.

Such an active point of view toward the material under study is the difference between the scientist and the historian. The operations research worker wants to understand operations so that they can be predicted and thus influenced. Sometimes the prediction and the understanding go hand in hand; one makes a tentative prediction and if it works out, the hypothesis is verified. A few examples will make this clearer than further generalities. The first example concerns the problem of understanding the interrelations between operational training, bombing accuracy and bomber effectiveness while conducting the strategic bombing of Japan.

Examples of Operations Research at Work

Certainly all the crews, which manned the *B-29's* used to bomb Japan, came to the operational base at Saipan with a great deal of prior training in bombing. One would suppose that, once they were on Saipan, they should spend all available flying time actually doing their job of bombing Japanese cities. It would seem, at first sight, inefficient for them to waste valuable time and gasoline doing any further practice when the real job was there to do. Nevertheless, the results of the early *B-29* raids on Japan were far from satisfactory. Errors of aim were large enough so that, on the average, less than 20 per cent of the bombs fell within 1,000 feet of their target. Surely this record needed improving, and a great deal of discussion went on in the command as to what should be done. Undoubtedly a new bombsight of greater complexity would improve the results, but this would cost a great deal in time and money, both to manufacture and to install in the airplanes.

The operations research worker, with the command, suggested that additional scored exercises might improve the results. After some hesitation it was decided to try this for a month or so; it might not help, but no other immediate action suggested itself. Accordingly, it was ordered that 20 per cent of the flying time of operational crews for a month be devoted to carefully scored practice bombing under simulated operational conditions, and that only 80 per cent of the time was to be spent on bombing Japan. The results were successful beyond anyone's expectation. Within the month the operational accuracy of bombing had more than doubled; and by the end of two months, more than half of the bombs dropped on Japan landed within 1,000 feet of their target. By devoting 20 per cent of the time of crew and airplane to operational training, the precision of bombing for the remaining 80 per cent was increased more than two and one-half times. Thus the over-all effectiveness of the bombing was more than doubled. This was enough improvement so that the installation of new bombsights was not required.

The operational accuracy of bombing more than doubled, during a trial period of one month in World War II, by devoting 20 per cent of flying time to carefully scored practice bombing, and 80 per cent to actual bombing of the enemy.

This example shows several of the characteristics of operations research. In the first place, the worker was a part of the staff, working with the operations officer. In addition to carrying out the statistical analyses to measure effectiveness, his contribution was to supply a certain experimental-mindedness characteristic of the scientist. Essentially, he said: "If my picture of the relation between training and accuracy is correct, then operational training will help. Let's try it and see." In many cases, of course, such experiments cannot be tried, and it is the duty of the officer to make the ultimate decision. For effective teamwork, the operations officer must realize that the operations research worker does not suggest such experiments out of idle curiosity, and the research worker must realize that the officer does not veto his suggestion (if he does) out of pure conservatism.

In the second place, this example shows the importance of continual measurement of the effectiveness of an operation and the use of the operations research worker in evaluating these measurements incessantly. In this case, a considerable amount of statistical analysis was necessary to separate various other effects (as,

for example, improved cruise control and weather) from the results so as to assess the actual effect of added training.

The next point to emphasize is that the improvement in effectiveness was obtained without the requirement of additional equipment; the equipment at hand was simply used more effectively. Of course, in many cases the results of the study of an operation have yielded valuable suggestions to the laboratories for improvement of weapons, but these are by-products of the research; the primary task is to get the most out of the men and material at hand.

It should be apparent by now that the mathematical theory of probability is of considerable importance in operations research. It turns up in nearly every study. No operation has a certain outcome, only a distribution of more or less probable outcomes. No one can evaluate operations without understanding probabilities. To evaluate strategic bombing, for instance, one must know the mean rate of aircraft aborts, the probable error of navigation of the usual crew, the probability of radar detection and of enemy fighter interception, the mean vulnerability of both fighter and bomber to damage by gunfire, the accuracy of antiaircraft fire, the probable error of bombing, and the expected damage function of the bomb — every item of which must be expressed in terms of probability. In many cases it is not sufficient to have an average value. One must know the spread of values: whether there are likely to be twice as many aircraft aborts, on a particular day, as on the average, or the chance of a bomb falling within 100 feet of the target when the probable error is 1,000 feet.

Importance of Quantitative Evaluations

In the cutthroat game of radar and radar countermeasure, it often happens that a countermove too early is at least as harmful as one too late. How is one to evaluate reports in order to decide what to do and when to do it? In 1944 our submarines in the Pacific were supplied with aircraft warning radar to help them escape detection by Japanese aircraft. After a few patrols, it was discovered that many submarine skippers did not use the set. More airplanes came in when they had it on, they said; the Japanese must have a set in their airplanes which picks up the radar and homes on it. An examination of patrol reports showed that the skippers were indeed correct in their facts; those submarines having radar on, reported rather more than three times as many airplanes as did those with their radar off. An order was prepared to remove the radar sets as a liability.

Harold M. Lambert

But wait a minute! The radar set has twice the range of a visual lookout and should cover four times the area. It therefore *should* report about four times as many airplanes, if radar and visual observations are equally effective; and the patrol reports really only proved that the radar was doing its job of better warning. In the end, an order went out to use the radar sets and to keep using them until "radar on" showed at least 10 times as many airplanes as "radar off" did. This never happened and at the end of the war it was verified that no Japanese airplane had had radar detection sets. A lack of quantitative understanding almost nullified the considerable usefulness of radar early warning in this case.

It should also be apparent that the newly developed fields of game theory and communications theory are of great utility in operations research. An example of the use of game theory lies in the aircraft-antisubmarine battle in the Bay of Biscay, off the coast of France, in the last war. The U-boat, as it went out from its base in France, had to come to the surface for a few hours a day to recharge batteries. The longer it ran on the surface, the sooner it could get out of range of the airplanes. The British first used visual sighting and flew only in the daytime. The U-boats, of course, surfaced only at night and submarine losses were small. The British then equipped a few airplanes with radar and searchlights for use at night. The problem was to determine how many such airplanes should be equipped and flown. If they all flew at night, the Germans would surface by day. Moreover, the night attack was not as deadly as the day one. Game theory determined what proportion of day and of night fliers should be maintained in order to keep the Germans most confused and in order to get the most U-boat kills per given cost in equipment, training, and men. Game theory also indicated what were the best tactics for the submarine; what percentage of hours it should surface by day and how often by night.

Many other problems of interest in operations research involve game theory. Certain aspects of the duel problem have turned out to be enlightening in the study of automobile traffic, for example. Other aspects arise in the study of sales fluctuations and the planning of inventory in a nationwide distribution of a product. The various opposing requirements to be balanced include the finite shelf life of the product, the loss of good will when the inventory runs out and items cannot be supplied on demand, and the additional cost of changing factory production too often to catch up on products

(*Continued on page 214*)

Education for Freedom

The Requirement for Self-Government among Men Appears to be a Fairly High Degree of Development of Intellectual and Moral Potentialities of the Individual

By JOSEPH H. KEENAN

THE word freedom, as presented in this article, is used to convey an ideal which has grown up in the Western democracies and which can best be signified by two words: dignity and responsibility. Here the word dignity signifies that the individual is of supreme importance, that his welfare is the object of all valid institutions; the word responsibility signifies that no higher authority exists than the individual man, for example, "that governments derive their just powers from the consent of the governed."

If we ask why we should educate for a free society – a democratic society – rather than for an authoritarian society, the answer must be that, over the past two centuries, at least, the institution known as Western democracy has satisfied more successfully the fundamental needs of man than any other institution. It has satisfied in greater measure his needs as an individual and his needs as a social being. For both aspects of his life, man requires freedom from ugliness, violence, and cruelty – with opportunity for developing their opposites: beauty, peace, and love. It is quite clear that this is true of all men, even of those outside the democratic area: otherwise, why should both Hitler and Stalin have proclaimed themselves the champions of peace?

Whereas dictators promise, democracies perform. Democracy has resulted in peace among diverse peoples and even among diverse nations who shared its doctrines. Tyranny, on the other hand, is at best an unstable equilibrium which will ultimately encounter the disturbance that will initiate drastic and violent change. Democracy is not merely freedom from oppression. The requirement for self-government among men appears to be a fairly high degree of development of the intellectual and moral potentialities of the individual. Nothing less than a wide dissemination and a general acceptance of the principles of free inquiry and of individual responsibility will do.

The contemplation of American democracy is not always edifying. When one observes a political campaign, or reads a McCarran Act, one is inclined to wonder whether the American citizen has any concept of either dignity or responsibility. Nevertheless, one might take the other, more optimistic, view to the effect that if the most stable government of the world can be based on such a meager education in the fundamentals of democracy, the possibilities that may result from a serious effort are indeed boundless.

Because of its emphasis on science, an institution like M.I.T. is in a peculiarly fortunate position in regard to education for a free society. It is not an accident that science and democracy grew up together. Science has provided us with intellectual integrity and objectivity – humility before the fact. It has emphasized the importance of definition of terms, logical procedure, and tests for validity. In its broadest sense, the scientific method is free inquiry itself. Percy W. Bridgman, Hollis Professor of Mathematics and Natural Philosophy at Harvard University, has said that the scientific method is the fullest possible use of intelligence, with no holds barred. In this sense, it is apparent that the scientific method must be relevant to virtually all human activity. Certainly it deals with all questions of social value, and thus in one stroke Bridgman has settled the question as to whether social sciences are really scientific.

And yet we must beware that we do not lose the broad view of the scientific method. Although the so-called natural sciences can give us valuable experience in logic, in tests for validity, and in objectivity, they are not sufficient for the educated man in a free society. They overemphasize the problem with the small number of independent variables, the problem to which there is one answer. Among scientists and engineers it is not uncommon to find a feeling of scorn for areas like economics or politics in which the variables are numerous and uncontrolled and the answer is many-valued. This attitude is strong evidence of deficiency in education, since it is in just these areas that the heaviest responsibilities of the individual, scientist or other, must lie.

It is most necessary, therefore, that our education for a free society should provide data on the behavior of man, as well as on the behavior of things. And so we come to history, philosophy, and the arts. It is not the intention in this article to discuss how, or in what measure, these should be taught. But however they are taught, the purpose should be, aside from gathering data, to give the student an experience in free inquiry, to stretch his intellectual capacity, and to build within him the awful sense of the ultimate and complete responsibility for himself and his civilization which he must shoulder.

The accomplishment of these noble ends is not just a matter of drafting curricula and selecting textbooks.

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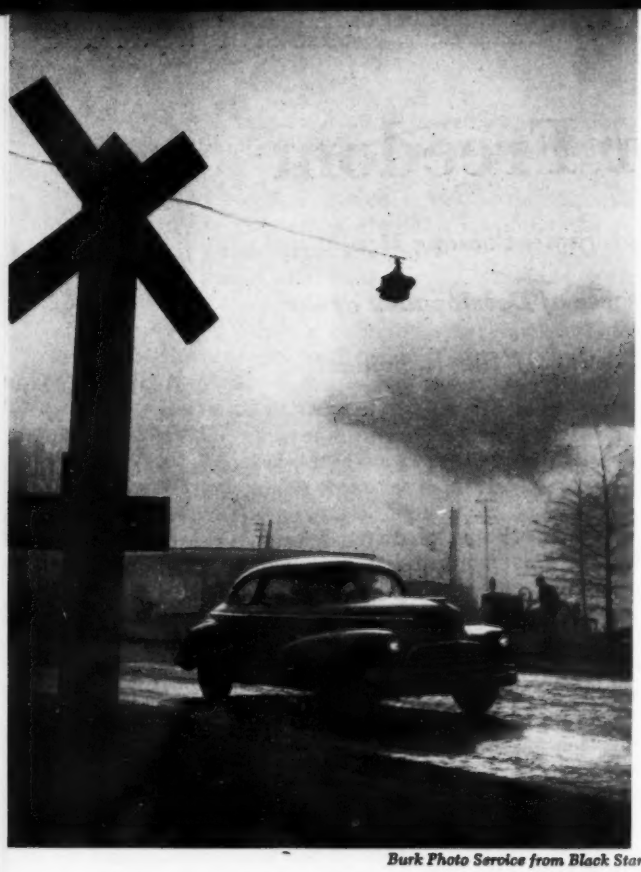

Burk Photo Service from Black Star

Automobile Safety

More Stringent Traffic Regulations for Pedestrians and Public Demand for Minor Engineering Changes Could Reduce Casualties Appreciably

By DAVID O. WOODBURY

SOMETHING is being done – or, more accurately, some thinking is being done – on the tragic problem of automobile accidents, which take a yearly toll of more than 30,000 lives and put one million people into the accident wards of hospitals. Those who are doing the thinking believe that the design of cars, in relation to passengers and pedestrians, has steadfastly ignored Newton's laws of motion, with the result that human beings are exposed to the mercy of very large forces of acceleration and deceleration without having adequate means to withstand them.

An elementary principle of shipping freight is that the goods must be securely fastened down, or packed together, so that the material cannot go adrift as the vehicle moves. In the event of a storm, cargo on a boat would certainly be smashed if a shipowner failed to secure it, and, in addition, his vessel could be ruined by damage inflicted by merchandise. The same principle is basic in all types of flying: cargo, passengers, and pilots are carefully restrained, and airplanes are designed to afford the passengers the utmost protection if a crash does occur.

But in the millions of automobiles rushing about on our highways, not one offers any provision for passenger safety in time of accident. Driver and riders are free to move, to be thrown about, or hurled through doors and windshields if sudden changes of speed or direction take place. Forces of 10 to 20 times that due to gravity (10 to 20G.) are common in automobile collisions; even when making an emergency stop with the brakes in traffic, the average deceleration of 0.75G. will throw a child against the windshield with sufficient force to cause a concussion. Yet both public and manufacturer have apparently ignored the danger, concentrating entirely upon the prevention of accidents rather than making cars safe. A cursory study of motor-accident statistics of the past 20 years quickly shows that the casualty trend, per passenger mile, is not downward. The reason for this is simple: The instinct for safety and a useful knowledge of the forces involved in accidents cannot be legislated.

Recently, work has been done at Cornell University in measuring the forces to which automobile riders are subjected, and recommendations have been made for the use of safety belts in cars. The most significant contribution so far, however, comes from an independent physicist, William W. Harper, of Pasadena, Calif., who was formerly an assistant to Robert A. Millikan at the California Institute of Technology.

Harper, who for many years was associated with the Pasadena Police Department as a consultant in accident cases, is at present engaged in expert witness work for the courts on the West Coast, and has analyzed thousands of traffic accidents in the light of the Newtonian forces involved. His recommendations, soon to be published, offer an interesting challenge to automobile owners and manufacturers alike. The gist of his findings is very simple, and his recommended remedies seem incontrovertible.

Seat belts, Harper says, are a prime requirement if we are to prevent car riders from being thrown against the dashboard, the windshield, or through the doors. But this is not all. He points out that car seats, which often weigh 100 pounds, are fastened down so flimsily that forces of three to five G. will usually tear them loose. Thus, in a crash of any consequence, the weight of the seat is added to that of the passenger, and

(*Concluded on page 218*)

Burton Holmes from Ewing Galloway

Founded in the Thirteenth Century, Stockholm is a modern city in every respect.

Study in Sweden

M.I.T. Graduates Broaden Their Education and Promote Good Will by Assisting in Research Programs Abroad

As Reported by **JACQUES A. F. HILL, ROBERT N. RANDALL, and RICHARD M. SCHOTLAND**

THE great success of the M.I.T. Foreign Student Summer Project during the last three years (see The Review for November, 1948) has called attention to the values to be gained from study and research abroad by advanced graduate students and research workers. To further promote this end, the Institute has planned a similar type of project for its own graduate students. During 1950 arrangements were made with three research institutes in Sweden (the High Voltage Research Institute at Uppsala, the Aeronautical Research Institute of Sweden at Stockholm, and the Stora Kopparbergs Steel Research at Domnarvet), for a group of M.I.T. students to engage in research in that country during the summer months.

Under arrangements worked out by the M.I.T. Foreign Study Committee,* the Swedish institutes accepted a number of graduate students for employment. The students were recommended by M.I.T. on the basis of special proficiency in fields of particular concern to the co-operating research organizations. The students were remunerated sufficiently in local currency to cover living and incidental expenses while in Sweden, and funds placed at the disposal of the Foreign Study Committee of M.I.T. assisted those in need in the payment of transportation between the United States and Sweden.

* The committee is composed of Professors Norman J. Padelford, chairman, Lawrence B. Anderson, '30, Paul M. Chalmers, Harold L. Hazen, '24, John T. Norton, '18, C. Richard Soderberg, '20, and Walter H. Stockmayer, '35.

In each case the M.I.T. students were employed as skilled research technicians on a comparable basis with native workers. This enabled the M.I.T. graduates not only to become familiar with foreign techniques in their own field, but in addition to work in close personal touch for a time with distinguished European scientists and engineers. Moreover, the arrangements permitted the men to develop friendships with young Swedish professional workers with like interests to their own. And informal opportunities allowed them to visit, as well, numerous scientific and industrial establishments in the Scandinavian area.

John R. M. Alger and Eugene B. Skolnikoff, graduates in 1950 of the Co-operative Course in Electrical Engineering, were both employed for two months at the High Voltage Research Institute at Uppsala, which is under the direction of Professor Harald Norinder. Under the direction of Oskars Salka and Laszlo Asztalos, they worked on a project for obtaining suitable analysis of the mechanism of the long spark. Richard M. Schotland, who received an S.B. in Electrical Engineering in 1948 and an S.M. in Meteorology in 1950, was also employed for the two summer months at the High Voltage Research Institute, specializing on measurements of light and heavy ion concentrations in the atmosphere and on the conductivity and potential of the atmosphere, under the direction of Reinhards Siksna and H. Israel. Jacques A. F. Hill, a graduate in 1947 of the Course in Aeronautical Engineering, and now working with the Division of Industrial Coöpera-

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Tapping of one of the big steel furnaces at the Domnarvet iron works of Stora Kopparbergs Bergslags Aktiebolag. Robert N. Randall, '50, is spending a year at this company which celebrated its 600th anniversary in 1947.

tion on the Naval Supersonic Research Project, spent the summer months at the Aeronautical Research Institute of Sweden located on the outskirts of Stockholm. Mr. Hill was working on a preliminary investigation of the possibility of transonic wind-tunnel testing using slotted walls in the test section. Robert N. Randall, a graduate in 1950 in the Metallurgy Course, began one year of research at Stora Kopparbergs Bergslags Aktiebolag at Falun, working in the research department under Professor Bo Kalling.

Reports from the overseas study project in the summer of 1950 indicated that it was genuinely useful to all concerned. Research workers in the Swedish institutes gained some familiarity with American ideas of techniques, instrumentation, and research procedures in the process of working together. The M.I.T. students in return learned a good deal about European technical education, Swedish research and industrial methods, Swedish professional advances, and the problems many foreign scientists face without elaborate apparatus and experimental data with which to work. Above all, both the M.I.T. students and those with whom they were associated experienced the rich values of international friendship derived from groups of like-minded scientists working together intimately on common problems across national lines.

Reports made to M.I.T. by three of the students — Messrs. Schotland, Hill, and Randall — describe some of the Swedish scientific institutions, their observations of working and living conditions in Sweden, and the experiences which they had while abroad under the M.I.T. foreign study project.

Swedish Research Facilities

The laboratories of the High Voltage Research Institute at Uppsala, where three of the five students worked, are well equipped for the particular type of research undertaken; for example, High Tension Hall has a two-megavolt Marx impulse generator, a 100,000-ampere current generator, two Van de Graaff generators, and a 500,000-volt transformer. Some of the smaller instruments found in laboratories in the United States, which are useful only because of their convenience, are frequently missing.

The scientists at the High Voltage Research Institute are outstanding men, both from the point of view of their scientific attainment and their personalities. Founded by Professor Harald Norinder of the University of Uppsala, one of Europe's leading authorities on high voltage and atmospheric tension, the Institute staff includes a number of eminent displaced scholars forced from their own continental universities by Soviet occupation, together with visiting scholars temporarily present in the summer period to participate in the Institute's field studies in atmospheric electricity. Among those at Uppsala in the summer of 1950 was H. Israel, one of the world's authorities on atmospheric electricity.

The Aeronautical Research Institute of Sweden, located on the outskirts of Stockholm, has a position in the aeronautical field in Sweden similar to that of the National Advisory Committee for Aeronautics in this country. It is directed by Bo Lundberg, who has in the past spent considerable time in aeronautical research and aviation industries in the United States and various European countries. While aeronautical work is done at other places in Sweden, such as the Royal Technical High School at Stockholm and the Swedish Aircraft Company (SAAB), the most elaborate and expensive equipment is located at the Aeronautical Research Institute, which is a government facility working both for the civil and military air services.

The work at the Aeronautical Research Institute is divided into two broad fields — aircraft structures and aerodynamics. The structures department has large testing machines which are capable of handling full-scale airplanes up to light twin-engine craft, a landing gear drop test machine, and many smaller machines for testing materials both statically and dynamically. The aerodynamics department has wind tunnels for subsonic, transonic, and supersonic testing. The test section diameters are 10 feet, 3 feet, and 9 inches respectively. The wind tunnels and their associated equipment are less expensively and less elaborately constructed than they would be here, except for the low-speed tunnel. The pump used for evacuating the vacuum tanks for the supersonic tunnel, for example, is a Packard-Merlin aircraft engine obtained from an Allied airplane which landed in Sweden during World War II. On the other hand, the models and the measuring equipment are very skillfully built and may even be superior to equivalent items in America.

The staff at the Aeronautical Research Institute seems very small when considering the ground to be covered. Until last year, only one man was employed for theoretical supersonic work, and he also had to supervise all experimental work in that field. Notwith-

standing the smallness of staff and limitations in basic equipment, a large amount of practical work has been going on at this research institute. Ingenuity and skilled effort have compensated for inadequacies in equipment.

The Stora Kopparbergs Bergslags Aktiebolag (translated as the Large Copper Mountain Company but commonly referred to in Sweden as Bergslaget) is a combined steel, paper, and chemical company. It owns three steel plants, two paper and pulp mills, and numerous mines and timber areas, with its activities located in the central part of Sweden with headquarters in Falun, a small city about 150 miles northwest of Stockholm. The company is believed by many to be the oldest corporation in the world. In 1947 the company celebrated its 600th anniversary.

Originally Bergslaget was exclusively a mining company operating the famous copper mine at Falun. Copper from this mine helped to finance the many wars of Sweden in the Sixteenth and Seventeenth Centuries. Much Swedish history has been connected with this mine in times of peace also. The distinctive red paint which covers almost every farm building and home in central Sweden is a product of this mine. In the Nineteenth Century, however, the rich copper ore began to be depleted and Bergslaget turned to iron and later to timber products for revenue. Situated as it is along the Dal River, it has ample water for use in manufacturing, for transport of logs, and for electric power.

The section of the research department which deals with iron and steel problems is called *Forskning-central*. This is headed by Professor Bo Kalling, one of Sweden's leading metallurgists. The department is located at the Domnarvet Ironworks in Borlänge, a city about 13 miles south of Falun. This plant, the largest steel plant in Sweden as to tonnage, employs about 2,800 men and produces about 210,000 tons of steel per year. It is currently being expanded so that the capacity will be doubled in the near future. The electric steel and basic Bessemer processes are used here to convert the blast furnace iron into steel. The majority of the tonnage comes from the basic Bessemer converters. The final products are primarily low-carbon rolled wire, strip, sheet, plate, and structural shapes. Alloy and stainless steels, together with sponge iron, are produced at another plant (Soderfors works — capacity 10,000 tons per year).

The efforts of the research department, which has seven engineers currently on its staff, are directed to problems in process and physical metallurgy. In addition to one section of the central plant laboratory, where most of the physical metallurgical work is handled, there is one whole building where work is conducted on both a laboratory scale and with pilot-plant equipment. For purposes of comparison, it is a building somewhat larger than the Metal Processing Building (no. 35) at M.I.T. This building houses offices, two laboratories, and a large work area for pilot-plant use. It has its own staff of laborers and artisans.

Much of the research work is concerned with the development of new processes and the efficient utilization of by-products. Work is carried out on problems which develop during the operation of the plant and also on ways to improve the company's products. Research projects at present include the control of nitrogen in steel, the effective use of oxygen in steel production, the removal of sulphur from iron and steel, and the efficient production of sponge iron. Whereas interest in the first three subjects is rather universal, the last problem, at least at present, is almost exclusively a Swedish one.

Sweden has always shown an interest in high purity irons, such as charcoal iron and sponge iron. In the last few years the price of charcoal has made the use of this material unprofitable, and therefore much attention has been given to the production of sponge iron as a source of high purity iron. This iron is used in the production of the famous Swedish cutlery and alloy steels, which the Swedish people feel should be made from pure materials.

Mr. Randall's research work is connected with problems involved in the control of sulphur and nitrogen in steel. Professor Kalling has given him much freedom in his work and several helpful suggestions. Mr. Randall finds the work interesting and stimulating. He reports that there is good teamwork among the engineers and that ideas are readily exchanged. The other engineers have been very generous in offering help and suggestions.

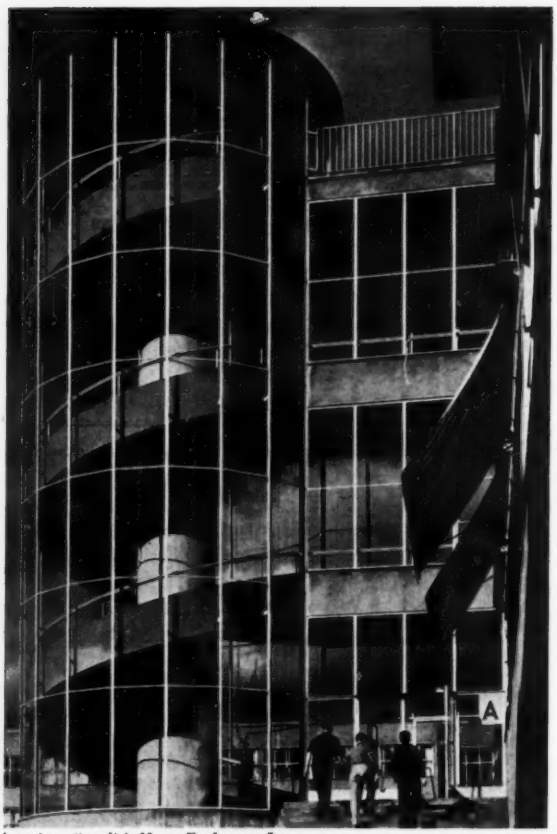
Travel

The M.I.T. student group at Uppsala was able to spend many week ends traveling in Sweden and elsewhere. Longer trips were made possible to Norway, Denmark, Finland, the Island of Gotland, and the Swedish Alps. An important part of these trips was the opportunity to make contacts while traveling; for example, while they were en route to Finland, Messrs. Schotland, Alger, and Skolnikoff met Professor Järvi of the University of Turku. He arranged hotel accommodations and invited them out to his villa on the Baltic.

Language

For Americans there is but a slight language problem in Sweden. Almost all Swedish engineers have six years of English in their training, and M.I.T. students found no trouble as far as professional work is concerned or in traveling. In the smaller towns one also can usually find people who at least know a little English. One problem, related to language, that does baffle many Americans at first, is the use of the metric system rather than the English system of units. Americans find it somewhat difficult to think of persons as being 188 centimeters long or weighing 84 kilograms.

The Swedish people, in general, appeared to be much more interested in learning foreign languages than are Americans. Most engineers know English and German and may know French as well as Spanish. Esperanto is fairly popular with the people in Sweden. In the early autumn the press is full of advertisements for language lessons. English is the most popular of the various languages offered. One school teaches both English and American. In Falun, during World War II, an impetus was given to the learning of the English language by the presence of about 400 American airmen who were interned there. Most of the girls in their twenties know English quite well now!



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This industrial school in Stockholm is typical of the modern educational institutions in Sweden, which are built to let in as much sunshine and daylight as possible.

Swedish is not too difficult to learn. It contains many English and German words, and the grammar, in many respects, is similar to English grammar. Even in the short summer period, the M.I.T. students found it possible to pick up a limited familiarity with the language, and found that this was important in getting the full benefit of their job and visit.

Living

All of the M.I.T. students enjoyed opportunities of associating closely with the people and workers living in the vicinity of the various research plants, thereby gaining an insight into the folkways and attitudes of the Swedish people.

Living accommodations at Uppsala were good. The High Voltage Research Institute provided the three M.I.T. students with two rooms and a kitchen in a nearby house – all equipped with comfortable modern furniture. The equivalent of $40 a month in Swedish currency was sufficient to cover the cost of meals and small incidental purchases.

Living accommodations in Stockholm for Mr. and Mrs. Hill were arranged by the Aeronautical Institute of Sweden. The two Americans shared an apartment with a Swedish engineer and his wife. The apartment was located fairly near the center of town. This arrangement was very happy for both couples as it provided an exchange of ideas about their respective countries.

Swedish Education

As the Swedish engineers are the product of an educational system somewhat different from the American, a comparison may be of value. A child in Sweden begins school when he is six or seven years old. He attends a "folk skola" or grammar school for five years and then can choose which of three paths to follow. He may attend for one more year and then conclude his education after attending a trade school for one year. Many children do this, but fewer are discontinuing now than have in the past. His second choice is to attend an intermediate school for five years and then the "gymnasium" (comparable to the U.S. high school), for two years. A third choice is to attend the grammar school for one more year, and then an intermediate school for three years, and the gymnasium for three years. In either of these two latter plans, he can drop out after completing a total of seven years of school.

Following the gymnasium a student planning to attend a university or technical high school takes a student examination, which is a comprehensive examination covering all his work and which is required for admission to a university. Those who successfully complete this examination wear a distinctive white cap.

Following the student examination, the Swedish boy generally spends nine months in the army, for every Swedish male between the ages of 20 and 45 is subject to military training and must receive at least the basic nine months' course. Those planning an engineering career then attend one of the several technical schools – the most prominent of which are in Stockholm and Gothenburg.

The standard course at the Royal Technical High School at Stockholm (KTH) is of no fixed length but usually takes four years and is begun at the age of 19 or 20. It leads to a degree rating somewhere between an S.B. and an S.M. The emphasis is on mathematics and fundamental science in the first two years, and professional topics in the last two. The aeronautical engineering course was discussed in detail and turned out to be almost exactly similar to the one at M.I.T.; for instance, the mimeographed students' notebooks on theoretical aerodynamics have the same chapter headings. As at Technology, there has lately been more emphasis on the humanities, and the Students' Union has been inviting poets and politicians, impartially, for talks in much the same way as the M.I.T. Lecture Series Committee.

To graduate from the Royal Technical High School (College) in Stockholm, one must, in addition to the prescribed course, have completed six months of practical work. This work consists of employment in industry where the student puts on overalls and works with the regular workmen in order to learn their problems and points of view. Before graduating he must also complete a thesis project. This work is often accomplished away from school in an industrial plant. When done in this way, the project amounts to about three months of solid work. The standards of the other technical schools are similar to the government-operated Stockholm school. The main difference is in the variety of courses offered and the quality of the teaching. It takes most students five years to complete an

engineering course, although it is possible to do it in four years.

As can be seen, the graduating Swedish engineer is somewhat older than his American counterpart. His academic training has been roughly the same, but he has had more practical experience and acquired more practical ability. This practical experience is important here, for few companies have training programs, and a young engineer is put directly into a responsible position.

One comment on an M.I.T. education was heard when a student from Stockholm expressed his astonishment at the number of courses in the humanities that are offered.

At Uppsala the university was closed during the summer months so that there was little opportunity for contact with student life. However, the university sponsors a course on Swedish life for foreign students and this gave the M.I.T. delegation the opportunity to meet many young people from various countries. The group attending this course comprised many nationalities, including a number of refugees from countries behind the Iron Curtain. The English language was a common denominator so Americans had no difficulty in becoming one of the group and entering into social life. Student gatherings were usually held around a coffee pot and began with discussion of world affairs and similar topics, often ending with a song fest. The students all seemed to have a good store of knowledge outside their own fields. Aside from being competent linguists, many had a lively interest in music and the arts.

In Stockholm too, things seemed pretty quiet during the summer. Most people took advantage of the summer weather to spend week ends outdoors — sailing and bicycling being favorite sports for which excellent facilities exist. A few gatherings (men students only) of some of the Aeronautical Research Institute engineers were held. Women seem to take a less active part in social life in Sweden than they do in the United States. As at Uppsala there would be lively discussions on serious topics, periodically interrupted by the serving of refreshments. Almost everyone was well acquainted with the humanities, and furthermore expressed doubts that culture was as well developed in the United States as in Sweden. In any case, the Swedish people were much better acquainted with our country than we were with theirs.

Customs and Life

General impressions of Sweden begin with the fact that it is a very prosperous country by most standards, and especially by comparison with its neighbors. Almost anything which is available in the United States can be obtained in Sweden; and only seldom is the price higher when converted at the current rate of exchange. On the same basis, salaries, as well as necessities such as food and rent, are about half as much as in this country. Consequently automobiles, refrigerators, and washing machines become luxury items owned by comparatively few. On the other hand, boats and summer homes are much more commonplace than in America.

In many ways Sweden is much like the United States but there are some things that immediately attract attention. One of the first things that was noticed was the conservativeness of the dress, the number of berets, and the knickers and short pants worn by the men. The short pants are only worn for sport or when relaxing at home, but the knickers are quite commonly worn as business dress. The color and design of American ties and socks usually draw amused comment. One also notices the distinctive folk dresses worn by many of the women in rural Sweden. Each village has its own distinctive design. On Sundays, at parties and weddings, and particularly on Mid-Summer's Day (June 23, a holiday in Sweden), one can see these decorative costumes.

The formality attendant on everyday relations in Sweden seems stiff and awkward to one used to the informality of America. The Swedish people do not feel comfortable speaking to a stranger on a train or at a public gathering. An introduction must always be made before conversation can begin. In Sweden men take their hats completely off not only when meeting a female acquaintance, but also when meeting male acquaintances and especially when meeting a superior. Everyone has a title and uses it. One is not addressed simply as "Mr. Swenson" but as "Engineer Swenson" or "Railroad Clerk Swenson" or "Technical Student Swenson." The necessity for shaking hands impresses the American visitor. At parties one proceeds, upon arriving, to shake hands with everyone present, and everyone arriving later will in turn shake hands with him. This can be a tiresome procedure at a big party.

Skål, perhaps the one Swedish word that is known throughout the world, is quickly reintroduced to the visitor to Sweden. The first time he uses it may be when he downs his first glass of *snapps*, a fiery beverage made from potatoes. Incidentally, some Swedish people have claimed that potatoes are one of the best things that were ever imported from America. Hard liquor is rationed in Sweden, but no one except a heavy drinker suffers hardship. Wine and beer are not rationed, but their manufacture and sale are con-

American Swedish News Exchange, Inc.

Old customs and colorful costumes are still treasured in Sweden, especially in the province of Dalecarlia, where observance of Midsummer Eve, shown here, is one of the oldest annual festivals of that country.

trolled. The beer is weaker than American beer and generally not very cold. (The best beer is exported.) One sight shocking to Mr. Randall was that of a man warming his beer by the stove before drinking it.

Coffee is the only other item that is rationed. It is both a popular beverage and a social institution. In Sweden one does not drink coffee with the meal but afterwards, often in the living room rather than in the dining room. It may be the center of a small meal in the late afternoon or early evening, particularly on week ends or when guests are present.

The *smörgasbord* is nowadays probably found more often in the United States than in Sweden. During World War II it was prohibited, and it has been slow to come back.

The amount of outdoor activity is impressive in Sweden. It is in part because of the decentralization of industry which permits many people to live within only a short bicycle ride of the open country. Another reason may be the long, dark winters. In the summer, everyone wants to get as much sun tan as possible. People almost move out of their houses; everyone stays outside as much as possible. Connected with this love of the sun is the love of gardening and of flowers. Almost everyone in Sweden will have a garden if he can, and his home will be filled with flowers and vines of every description.

One other nice feature of Swedish life should be mentioned. In almost every Swedish community except Stockholm, there is a *Folkets Park* and a *Folkets Hus* (People's Park and People's Theater). Here, at the park in the summer and the theater in the winter, are presented plays, ballets, speakers, and other attractions. The drama may be presented by a resident company or by the State Theater, which brings the plays of Stockholm's theaters, together with the actors, to every part of Sweden. No matter where one lives, there is opportunity to see some of the best stage productions that are to be seen in Sweden.

Despite all these things in Sweden, there are some things that are missed. There are few automobiles, and they are considered a luxury. There are no large, juicy steaks, and there is more fish in one's diet. Basically, however, life is about the same as in the United States. Although luxury items are more expensive and more things are considered luxuries, food, taxes, and lodging take a smaller per cent of one's income so that one has a greater part to spend on other things.

Hydroelectric station. Much of Sweden's power is derived from its rivers. Here is shown the Långhags hydroelectric plant of Stora Kopparbergs Bergslags Aktiebolag, on the Dalälven River.

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Politics and Social Conditions

Sweden, along with the other Scandinavian countries, has been compared to England in regard to socialism. Sweden, however, has not gone as far as England, and Mr. Randall reports that most of the Swedish people he has met do not think of their country as being socialist. As these people have been mostly engineers, the view may be somewhat misleading.

The M.I.T. groups at Uppsala and Stockholm reported that socialism seemed pretty generally accepted by the people they met. They did not hear any criticism of the principle such as one hears from so many people in America. There were some complaints about the high taxes, which amount roughly to 20 per cent on a salary of $120 a month. However, this tax pays for a very complete welfare program, including free medical care in almost all cases. During the campaigns for the municipal elections in September, the other parties did not oppose the welfare aspects of the socialist program. The Conservatives promised to reduce taxes and the Liberals promised to provide more benefits than the Socialists. The result was that the former lost ground while the latter gained – the Social Democrats winning as usual.

Workers are very proud of the benefits that are available to them in Sweden. There has been much boasting about the social legislation which has given the Swedish people a high standard of health and some protection in their old age. On the other hand, the engineers have said that often a man who is away from work, because of illness or injury, may make more money than if he were working. This quirk of the law, together with the labor shortage in Sweden, makes it very difficult to keep absenteeism to a minimum and to maintain discipline. It is also more difficult to enforce safety regulations. There is not the safety consciousness in the Swedish worker that there is in the American. Management in some industries has found that when health benefits were increased, the accident rate was also increased. In any case, little is done at present, to promote safety. One notices immediately the lack of safety features that are commonplace in most American industrial plants.

All feel that medical costs are very low in Sweden. It has been said that Swedish people, living in America, have sometimes gone back to Sweden for operations. Medicine is not socialized as in Great Britain, but there is a medical plan run by the government which works in somewhat the same way as the Blue Cross Plan. This covers everyone, and the rates are very low.

As in England, the railroads are owned by the government. The last portion to be taken over was that between Gävle and Gothenburg, which was placed under state control about three years ago. One opinion seems to be that the railroads are well operated, but that they were operated better when the government had to compete with a private operator. One can cer-

(*Continued on page 210*)

THE INSTITUTE GAZETTE

PREPARED IN COLLABORATION WITH THE TECHNOLOGY NEWS SERVICE

Awards to Compton

KARL T. COMPTON, chairman of the M.I.T. Corporation, was the recipient of two high honors in recognition of his work in advancing the nation's welfare through technological progress.

The 1950 Hoover Medal for "distinguished public service" was presented to Dr. Compton at the winter meeting of the American Institute of Electrical Engineers in New York. On behalf of the four major engineering societies in this country, the Hoover Medal was awarded in tribute to a "great leader in engineering education who has had a profound influence on the development of science and engineering and has devoted himself wholeheartedly to the welfare of the nation, both in times of peace and in times of war." Dr. Compton is the twelfth engineer to receive the medal since it was first presented to former President Hoover in 1930 for humanitarian accomplishments.

From the Research Society of America, Dr. Compton received the $1,000 William Procter Prize for scientific achievement. The presentation was made during the recent meeting of the American Association for the Advancement of Science in Cleveland. Much as the honorary research fraternity, Sigma Xi, with which it is associated, recognizes outstanding achievement in academic circles, the Research Society of America recognizes outstanding research in industry.

Biochemical Engineering Course

RECENT developments in the production of pharmaceuticals and antibiotics, and in the food and fermentation industries, have indicated a strong need for technical personnel with training in the basic biological sciences and in engineering as represented by Chemical Engineering. In order to make such training available to students who wish to enter this field, a new course leading to the degree of bachelor of science in biochemical engineering has been instituted as Option XX-B in the Department of Food Technology. Graduate work for qualified students is also available, and a research program is in progress.

The curriculum now offered is basically the undergraduate curriculum in Chemical Engineering with modifications to allow courses in biology, bacteriology, microbiology, and biochemistry. All courses contained in the curriculum are currently offered by various Departments at the Institute; however, if warranted by future enrollment, several new courses are planned which will give the students a more thorough background in microbiology and biochemistry. New courses covering the Chemical Engineering subjects of industrial chemistry and unit operations are also being developed in the Department of Food Technology in which the emphasis will be on the biological, rather than the chemical, industry.

On the Freshman Roster

THIRTY-SEVEN freshmen who registered in the first-year class at M.I.T. this fall were re-enacting their parents' actions of a generation or so ago. The present count of the Freshman Class is 792 and of this number there are 35 sons and two daughters of Alumni of the Institute. The distaff side being in the minority, we note particularly in the listing below, Miss Marilyn Fraser, daughter of Alfred A. Fraser, '20, and Miss Carolyn E. Hannauer, daughter of the late Louis Hannauer, '32.

With the realization that the humanities and social sciences now play a stronger part in the curriculum of an engineering school, Alumni will watch with interest the manner in which their children will apply the same fundamental principles of science and technology which they learned as freshmen two decades or more ago. Although influence, however indirect, should not be brought to bear in the selection of a college, the Institute welcomes with pleasure the following who undoubtedly have been exposed to a slight M.I.T. aura:

Student	*Parent*
John L. Allen	Lawrence H. Allen, '20
Joseph K. Allphin	Willard J. Allphin, '25
Richard P. Blye	Paul W. Blye, '19
Henry T. Brockelman	Bernard B. Brockelman, '29
Charles W. Burnham	Charles H. Burnham, '22
Charles J. Carpenter	C. Clinton Carpenter, '16
Paul B. Carty	Maurice W. Carty, '04
Donald A. Coleman	Albert F. Coleman, '31
James J. Coles	James A. Coles, '25
Evan T. Colton	H. Seymour Colton, '21
Gordon R. Comings	Edward W. Comings, '34
James H. Davidson	Jesse I. Davidson, '27
Edward L. Davis	Malcolm G. Davis, '25
Paul R. Drouilhet, Jr.	Paul R. Drouilhet, '37
Herbert H. Ellis	Ray C. Ellis, '22
Peter Felsenthal	Robert M. Felsenthal, '21
Emerson K. Fletcher	Ralph A. Fletcher, '16
Richard S. Foster	F. Leroy Foster, '25
Marilyn Fraser	Alfred A. Fraser, '20
Raymond F. Freeman	Raymond A. Freeman, '26
Paul E. Gabrenas	Anthony P. Gabrenas, '26
Erik M. Gelotte	Ernest N. Gelotte, '23
Roger L. Griffin, Jr.	Roger L. Griffin, '24
Peter E. Griswold	Earle A. Griswold, '23
Carolyn E. Hannauer	Louis Hannauer, '32 *(deceased)*
Ernest C. Hinck, 3d	Ernest C. Hinck, Jr., '27
Charles E. Loud, Jr.	Charles E. Loud, '23
Melvin R. Mattson	John B. Mattson, '21
Decker G. McAllister, Jr.	Decker G. McAllister, '21
John E. McNary	Herbert L. McNary, '18
Donald R. Mott	Edward E. Mott, '27
Emmanuel J. Otis	John P. Otis, '18 (Vokhliotes)
William B. Price	Richard P. Price, '25
Benjamin T. Rauber, Jr.	Benjamin T. Rauber, '14
Whitman A. Richards	Arklay S. Richards, '19
Mahlon R. Saibel	Edward A. Saibel, '24
Richard D. Tooley	Douglas A. Tooley, '28

Course I Grows

THE continued growth of the Department of Civil and Sanitary Engineering during the past year, which emphasizes its remarkable expansion during the five years that it has been headed by Professor John B. Wilbur, '26, was favorably noted during meetings of this Department's Visiting Committee* on March 6 and 7, 1950. Since 1945, the Department enrollment has grown from 82 to 298, an increase of 260 per cent. Not since 1926 have there been as many students who signified a desire to register in this Department of the Institute.

The increase in sponsored research during this same interval is even more striking. Five years ago there was no program of sponsored research, while today the research contracts in effect total $364,000 – with this program shared almost equally between the Divisions of Structural Engineering, Soil Mechanics, Hydraulic Engineering, and Sanitary Engineering. The projects involved are varied and important, and are of special value in stimulating the educational program of the Department, while at the same time indicating the importance of continuing research.

The growth of laboratory facilities during the past five years also deserves special mention. The new William Thompson Sedgwick Laboratories of Sanitary Science, with their engineering, chemistry, and bacteriology sections, have been developed. The Photogrammetry Laboratory is playing a significant part in teaching courses in surveying. The structural laboratories have been augmented by the Structural Dynamics Laboratory and by the Concrete Laboratory, that is now being rebuilt. The Soil Mechanics Laboratory has been expanded to include a section devoted to chemical and thermal analysis. Most important of all, after years of planning and discussion, the construction of the new Hydrodynamics Laboratory has been completed and the building is in use, located on Vassar Street, Cambridge.

With these new facilities, an increase in the quota for graduate students should be considered. In particular, the completion of the Hydrodynamics Laboratory will make it possible for the Institute to expand its field of influence. A number of inquiries from qualified students of foreign countries suggests that, in the field of hydraulics especially, restrictions in the enrollment of foreign students should be eased since the fields of civil and sanitary engineering are of particular significance in the less developed portions of the world. Undue restrictions regarding the enrollment of foreign students in these fields can curtail the opportunities of the Institute for effective contribution on a world-wide basis.

The courses in hydraulics have been expanded during the past few years, but in view of the Institute's unusually favorable position in this field with respect to both staff and facilities, still further expansion should be considered. A broadening of courses dealing with hydraulic engineering, and the addition of courses in hydraulic machinery are desirable. The field of transportation engineering appears to offer unique opportunities for service on the part of the Department to a degree beyond that developed at the present time, since traffic congestion is a major problem in the metropolitan areas and airport design has yet to evolve on an over-all functional basis that is well adapted to operational problems. The Committee believes that the social and economic importance of these and similar aspects of transportation problems warrant a consideration of expanding the work of the Department in this field.

The Committee favors the proposal, now being considered by the Sanitary Division, to offer a course leading to the degree of master of science in sanitary science. Such a program would emphasize the chemistry, bacteriology, and biology of the operational and research phases of Sanitary Engineering, and deal less with the design phases of the field. While it is expected that attention will continue to center on the degree in Sanitary Engineering, the proposed degree will broaden the scope of work being done by the Division. This can be accomplished without offering any new subjects.

The Committee is impressed by the progress made in the Department during the past five years, by the vitality of its present condition, and by its constructive plans for the future. The Department is ably staffed by leading teachers, and the policy of bringing people with first-class talent to the staff of the Department, and providing them with facilities that permit them to develop their areas of endeavor, is leading to results that, though already notable, hold even more promise for the future.

Economists Parley

THE Visiting Committee on the Department of Economics and Social Science* held its meeting on June 8, 1949. Members of the staff present were: John E. Burchard, '23, Dean of Humanities, Professor Ralph E. Freeman, Professor Charles A. Myers, and E. Cary Brown, Assistant Professor of Economics. James R. Killian, Jr., '26, President of M.I.T. joined the Committee for the luncheon period.

The Committee's report of a year ago was reviewed as a point of departure. It was recalled that the earlier report suggested a broadening of the list of required readings for the course in economic principles, with a view to more adequate recognition of the varying points of view regarding economic theories. The staff presented a number of examples of material which is now being used for this purpose. It was the feeling of the Committee members that much better balance exists in the reading material. The student now appears to be getting a more adequate presentation of orthodox, or classical, thinking which he can contrast and compare with some of the newer theories. The Committee believes that this will stimulate more careful and critical economic analysis on the part of the

* Members of this Committee for 1949–1950 were: Thomas C. Desmond, '09, chairman, Allan R. Cullimore, '07, Richard H. Gould, '11, C. George Dandrow, '22, George J. Leness, '26, Boris A. Bakhmeteff, and Thomas F. Farrell.

* Members of this Committee for 1948–1949 were: Charles E. Spencer, Jr., chairman, Hugh Pastoriza, '07, Ellis W. Brewster, '13, Oscar S. Cox, '27, William A. Coolidge, Beardsley Ruml, and Samuel S. Stratton.

student and not leave him without an anchor, should some of the more recent and partially tested theories prove inadequate to these changing times.

The Committee devoted much time to a consideration of Course XIV, Economics and Engineering. This Course is designed for those planning to enter fields where the knowledge of economics is of major importance, since the two optional fields are Human Relations and Industrial Economics. On the other hand, in terms of units, 60 per cent of the emphasis is on engineering, science, and mathematics; and 40 per cent of the time is devoted to subjects in the Division of Humanities, such as languages, English, history, business administration, economics, and other social sciences. The opinion had been expressed that this requirement should be relaxed to allow somewhat greater emphasis in the broad field of social studies. After some discussion, it was decided that this is a matter which could much more appropriately be decided by the Administration, should it decide to look into this further.

On Stage

GRATIFYING to the Institute was a request for a program of *The Grand Duke* – the first American showing of Gilbert and Sullivan's opera – which formed a part of the Tech Show given at the Hollis Street Theater in Boston on May 3, 1901.

The appeal emanated from the Pierpont Morgan Library in New York City, which recently opened a public exhibition devoted to the work of Gilbert and Sullivan. The Library, which perpetuates the collections begun by J. Pierpont Morgan, is one of the richest in resources in the United States and its exhibitions are famous. It is well known for its special collections of illuminated manuscripts, incunabula, rare books, etchings, original drawings, coins, and metals.

Unfortunately, the Institute did not have a program of *The Grand Duke* available but an excellent poster was found in the M.I.T. archives and loaned through the Hayden Library for the exhibition. Examining old copies of *The Tech*, however, ample news and editorial comment referred directly to Tech Show. On March 7 a last-minute bulletin announced that "a Gilbert and Sullivan opera which has never been hitherto produced in this country" would be featured. "*The Grand Duke* is a brilliantly amusing and picturesque bit of nonsense, admirably adapted to the needs of a college show, and to have the distinction of giving it its first presentation on the American stage, is no small feather in the theatrical cap of 'Tech.'"

The production committee included Allan Winter Rowe, '01,* James B. Laws, '01,* and Dr. William J. Mixter, '02. The show was put into rehearsal in early March and was reported in the issue of March 28 in most encouraging terms. Lewis Emery, '99,* was chosen as the leading lady, Matthew C. Brush, '01,* as Ernest, Herman O. Blatt, '04, as Ludwig, and the title role was awarded to James Driscoll, '02. Dr. Rowe, Thomas G. McDougall, '04, Gerald F. Loughlin, '03,* Paul McC. Paine, '04, and Selskar M. Gunn, '04,* completed the roster of principals. Among the features were a delightful "statutory duel" with playing cards (as shown in the poster reproduced on this page), a ballet, and a Dutch sabot dance of 10 peasants dressed in the national colors of orange and yellow. Large advance ticket sales were reported, and in due course Tech Show was presented before a large and appreciative audience. In the issue of May 9, the production was reviewed critically with the conclusion, "Considered as a whole *The Grand Duke* was a decided success."

Reproduction of poster loaned by Hayden Library to Pierpont Morgan Library, New York City, for inclusion in exhibition of Gilbert and Sullivan's works.

Almost half a century has passed since the *première* of *The Grand Duke* at M.I.T., but Tech Show goes on, and *The Tech* itself, now a full-fledged biweekly, continues to record life at the Institute for the present and for the future.

Outstanding Electrical Engineers

THREE recent graduates of the Institute's Course in Electrical Engineering were singled out for high honors as a result of outstanding achievements in their professional fields.

Donald P. Campbell, '43, has been awarded the Eta Kappa Nu plaque in commemoration of his selection as "the most outstanding young electrical engineer for 1950." Dr. Campbell is an assistant professor of electrical engineering at the Institute, and has made significant contributions in applying servomechanisms to industrial operations.

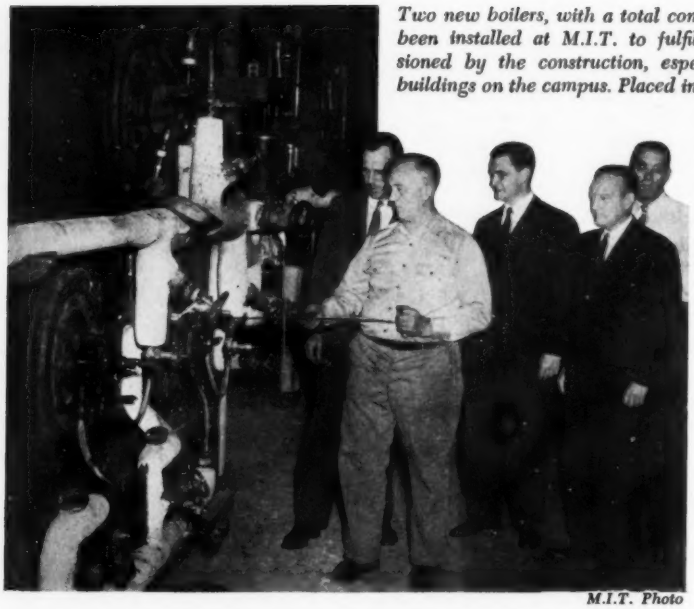
Robert W. Mayer, '41, was the recipient of an honorable mention certificate from Eta Kappa Nu, honorary electrical society. The presentation was made during the winter general meeting of the American Institute of Electrical Engineers.

Ralph J. Kochenburger, '40, received the Alfred Noble prize for 1950 for his original studies on automatic-control systems. The Noble prize is a joint award of the four national engineering societies and the Western Society of Engineers. The award has been made to Dr. Kochenburger for his paper which was read at last year's meeting of the American Institute of Electrical Engineers.

Director of Business Administration

THE appointment of Robert M. Kimball, '33, as Director of Business Administration at Technology, has been announced by President Killian. In this ad-

* Deceased.



M.I.T. Photo

Two new boilers, with a total combined capacity of 140,000 pounds per hour, have been installed at M.I.T. to fulfill the steam requirements of the Institute occasioned by the construction, especially within the past four years, of additional buildings on the campus. Placed in service on October 23, 1950, and January 4, 1951, respectively, these two boilers are replacements of installations of 1916 when M.I.T.'s first power plant was constructed in Cambridge. The original steam requirements were supplied at two pressure levels: the higher level, at boiler pressure of approximately 185 pounds per square inch and 450 degrees F. temperature, provided steam for laboratory use and certain service requirements; and at the lower level, at the exhaust pressure of one to two pounds per square inch, provided building heating.

Lighting off the second new boiler in January were (from left to right): *Robert M. Kimball, '33, Director, Division of Business Administration; Verner G. R. Johnson, Foreman, Boiler Room; Joseph J. Snyder, 2–44, Treasurer; Jerome H. Barraford, Assistant Superintendent, Buildings and Power; and Charles G. Turgis, Chief Engineer, Boiler Room.*

ministrative post, Mr. Kimball, as head of the new Division of Business Administration, will direct the nonacademic activities of the Institute.

He will serve as chairman of the Building Committee, and direct the Department of Buildings and Power, the Office of Housing and Dining Services, the Personnel Office, and the Safety Office.

Acting Head

PROFESSOR Bernard E. Proctor, '23, Director of the Samuel Cate Prescott Laboratories of Food Technology, has been appointed acting head of the Department of Food Technology, following the resignation of Professor William L. Campbell, '15, who has accepted a position in industry.

Hull and Salt Spray

THE Visiting Committee on the Department of Naval Architecture and Marine Engineering* convened on May 19, 1950, in the office of Vice Admiral Edward L. Cochrane, '20, formerly Head of the Department, now on leave of absence in government service since September, 1950.

The allocation to this Department of the rooms formerly occupied by the Dard Hunter Paper Museum, now housed in the new Charles Hayden Memorial Library, assures adequate space in all areas under present methods of operation. The progress which has been made on the construction of the new Ship Model Towing Tank is particularly gratifying. In addition, a small tank, or stability basin, is being designed for laboratory studies of the stability of ships in both intact and damaged conditions, of end-on and sideways launchings, and of similar hydromechanic problems. It is anticipated that this tank, as well as the Ship Model Towing Tank, can be ready by the spring of 1951. The opening of the Ship Model Towing Tank and of the stability basin will strengthen the facilities of the Department materially. To gain the benefits expected from them, however, an increase in teaching and research staff is imperative. For the school year 1950–1951, at least, this need will be met by adding an instructor and a half-time teaching assistant to the Department's staff.

With the transfer of Economics and Industrial Relations material to the new Charles Hayden Memorial Library, additional space has been made available in Building 5 for the Engineering and Naval Architecture Library. The Committee urges early action in effecting the plans to provide for storing, with suitable security, and making readily available the valuable collection of nautical books formerly in the Hart Nautical Museum and also for taking custody and handling the theses libraries of the various engineering departments served. The replacement in this library of the reference books essential for the work of the considerable number of students using this branch is a matter of urgency. These books should manifestly include atlases, current books and periodicals on naval architecture and marine engineering, indexes, a modern encyclopedia, suitable foreign language dictionaries, and current yearbooks. It also appears important to provide good daily newspapers in the branch libraries, but in this respect the Engineering and Naval Architecture Library is poorly supplied.

The Committee heartily endorsed the plan to have students in Course XIII-C, Marine Transportation, take their training at sea during the summer periods. A plan for the students in Course XIII, Naval Architecture and Marine Engineering, to obtain sea experi-

(*Concluded on page 208*)

* Members of this Committee for 1949–1950 were: William S. Newell, '99, chairman, Frederick S. Blackall, Jr., '22, Richard W. Berry, '32, Eugene P. Worthen, '32, Rear Admiral David H. Clark, Victor M. Cutter, and Robert C. Lee.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

This is Revere's Sesqui-Centennial Year. One hundred and fifty years of increasing business success is something out of the ordinary, even though there are a few companies in other industries as old or even older. This company dates back to 1801, the year Paul Revere started the first copper mill in this country, in Canton, Massachusetts. People usually think of him as a great patriot; he was also an artist and craftsman whose copper engravings and silverware are museum pieces today. In addition, he was a businessman, realizing that he could prosper only by offering better products and improved service to government, industry and the public. In labor relations he probably was a pioneer, because he paid somewhat better than going wages, in order to enlist to the full the skills his business required. Few men of his time could equal him in vision and resourcefulness.

A spirit of inquiry, investigation, research, was one of his characteristics. Writing of his efforts to find how to work copper, he reports: "I determined if possible to find the Secret & have the pleasure to say, after a great many trials and considerable expense I gained it." His eldest son, Joseph Warren Revere, who succeeded him upon his death in 1818, went abroad in 1804 to increase his knowledge by visiting the European copper fabricators. This was in all probability the beginning of research by any copper and brass company in this country. In addition, the Revere mill continued to make independent investigations. As a result, Revere became known not only as the preferred American source of copper and copper alloys, but of information about them. This was so outstandingly the case that when one of Paul Revere's friends, Levi Hollingsworth, saw a need for a copper and brass mill in Baltimore he asked Revere for advice, and was given it in full generosity. It is interesting to note that years later the Hollingsworth mill in Baltimore became the nucleus of the present Revere operations in that city.

When you consider Paul Revere's remarkable combination of art, skill, business acumen, recognition of the importance of research, it becomes possible to understand how a business so firmly founded could come down to today, larger than he ever imagined, and in proportion to the size of the country, just as important as it was in his own day. He was one of a number of men who put the United States on the path to greatness, not only politically but industrially.

As we look about the present Revere organization we find close links with the past, complete contact with the present, and great future promise. We are not only in copper and its alloys, but have been in aluminum alloys since 1922. More recently, we began to make Revere Ware, copper-clad stainless steel cooking utensils, now serving in American homes everywhere. Applied research, working as did Paul Revere but with greatly improved methods, continually uncovers new prospects for the future. In personnel, it has always been a Revere principle to give enthusiastic aggressive and capable youth its chance as well as its training. Thus we are old and experienced, but ever new and imaginative. In this our Sesqui-Centennial Year we give tribute not only to those who have helped us grow since 1801, but also promise a continually increasing measure of future service.

And while we mark our 150th Anniversary we do not forget that the brass and copper industry, now including a number of venerable and honorable companies, joins with us in playing a vital part in American life. We are proud not only of ourselves, but of our entire industry.

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THE INSTITUTE GAZETTE

(*Concluded from page 206*)

ence during their undergraduate training was also regarded as a very worth-while objective and was also highly recommended. The Committee was pleased to learn that a laboratory for the study of the structural problems peculiar to ships is being considered in the Department. In ship structures, the relatively heavy plating, rather than the frame, presents unusual problems not found in usual shore structures nor, heretofore, in airplane frames. Thus the proposed laboratory offers the Institute an excellent opportunity to conduct significant studies in a most promising field. Although no specific proposals or recommendations for the laboratory were ready to be discussed, the Committee wishes to offer every encouragement to the early culmination of this proposed educational facility.

The continued progress in the development of the collections of comparative ship models in the Hart Nautical Museum was noted with interest. The Committee renewed its strong recommendation of last year that the half bay just to the north of the entrance to the museum be returned to the Department. Return of this space would greatly enhance the appearance of the museum as well as the entrance to Building 5. It would also provide much needed space for two large exhibit cases already on hand for which no proper space is now available. The transfer of these two exhibit cases to the museum proper would also make possible a display of models showing the evolution of steamships, corresponding to the present series of models showing the evolution of ocean-going sailing vessels.

The Committee was pleased to observe the spirit of helpful co-operation mingled with critical evaluation of the curricula on the part of the Department's staff. This is undoubtedly an important factor in the rising interest and imagination of the students. It is also gratifying to note that the placement record of the students of this Department continues to be excellent.

Housing and Defense

THE relationship of housing and the housing industry to the nation's defense mobilization was the subject of a conference on "Housing: A National Security Resource" at M.I.T. on January 19 and 20.

The two-day meeting, to which top-level government and industrial officials were invited, was sponsored by the M.I.T. School of Architecture and Planning and the Bemis Foundation; with the assistance of the Departments of Economics and Social Science, Building Engineering and Construction, and Mechanical Engineering.

The conference was the culmination of a nearly full-time course in industrialized housing as a national resource. Because present-day housing is immobile, according to Carl Koch, Assistant Professor of Architecture, the decentralization of industry has been accompanied by serious housing problems. For security it is vital that labor's housing be decentralized.

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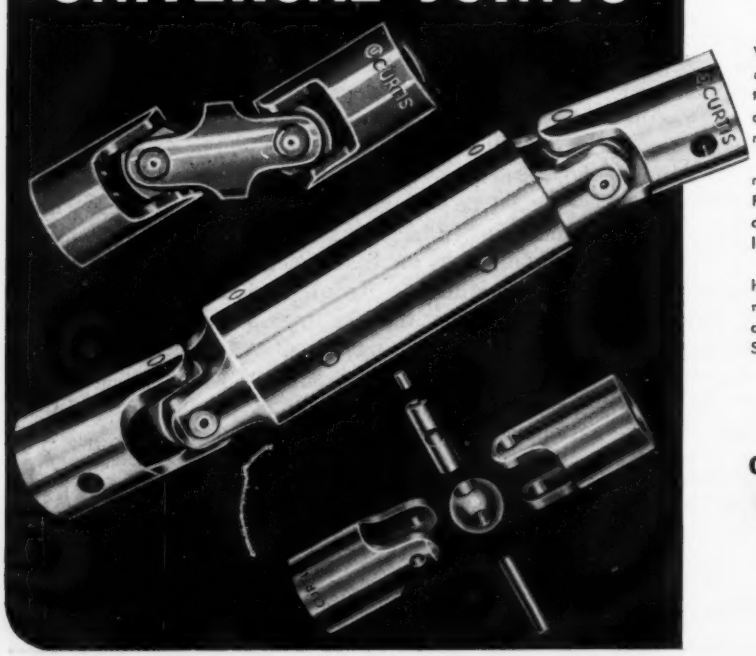

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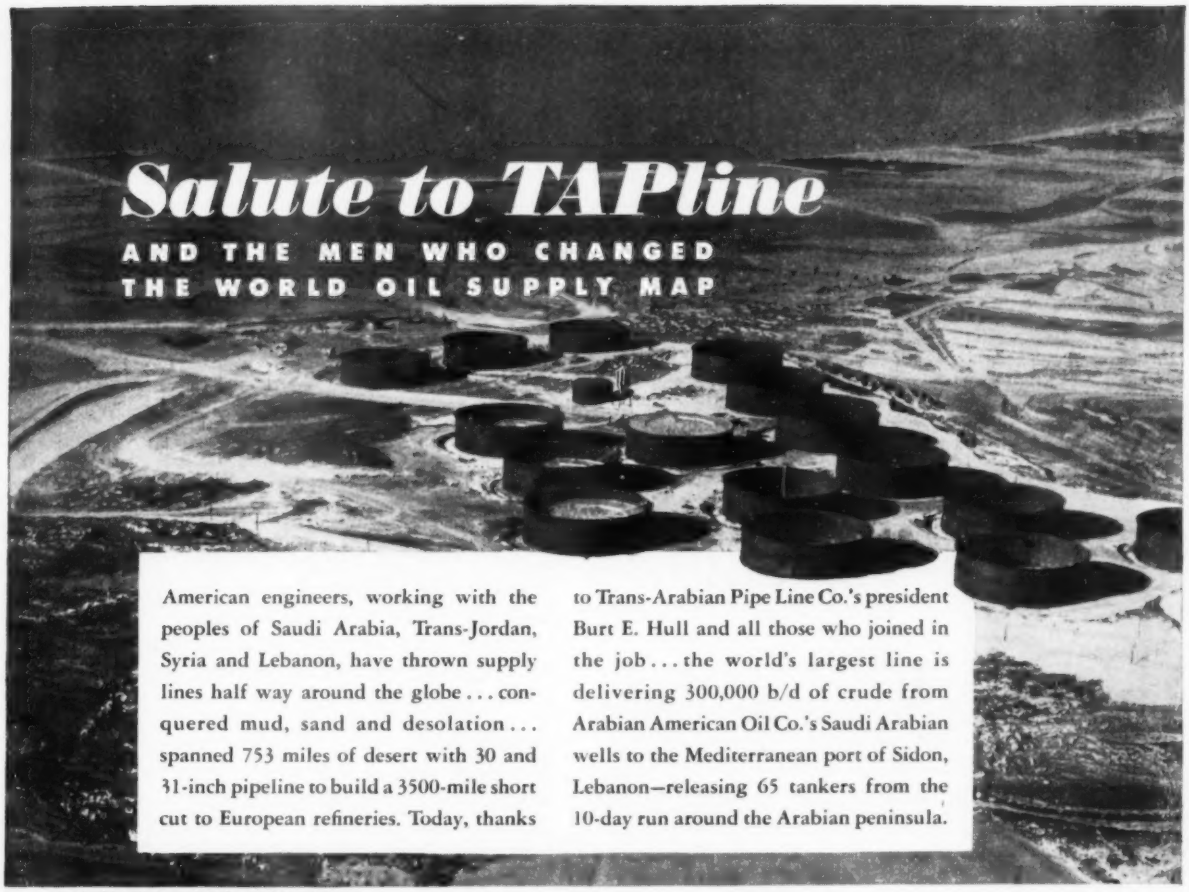

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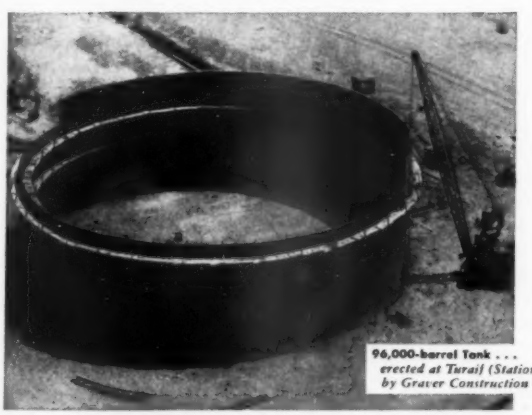
Looking Westward to the Mediterranean Sea . . . *at Sidon where Graver Construction Co. erected terminal tankage of nearly three million barrels.*



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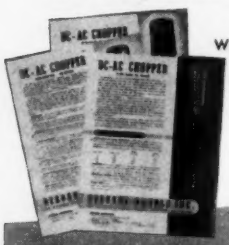

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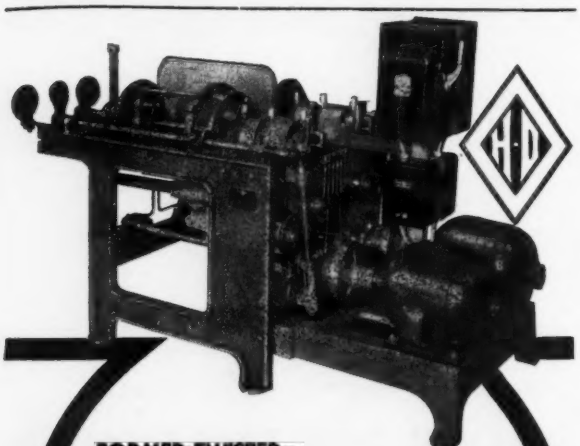

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STUDY IN SWEDEN

(*Continued from page 202*)

tainly agree that they are well run now, and one is particularly impressed by the amount of electrification and the neatness of the stations; for instance, in Gothenburg and in many of the smaller towns, the station managers have planted flowers around and in the stations and made their buildings quite attractive.

Steel has not been nationalized. However, the government is building a steel plant in the Far North, at Luleå on the Gulf of Bothnia. The engineers regard the location as poor because of the distance from markets and because the port is closed for several months in the winter. It is, however, near the large iron ore deposits at Kiruna. This steel mill will have a capacity when finished of about 400,000 tons per year. The government is finding that this plant is proving to be very costly. At Domnarvet expansion costs about 50 crowns per metric ton ($8.80 per short ton), but at Luleå it costs about 100 crowns per metric ton. The government has also had difficulty in obtaining skilled engineering personnel both because of the location near the Arctic Circle and because of the feeling among many of the engineers that they don't want the plant to be too successful and thereby lead to further government intervention in industry.

The Swedish people are rather proud of their co-operative movement. They hasten to state that co-operatives are not run by the government, are not monopolies, and must compete with private enterprises. Perhaps 4 per cent of the industrial enterprises are owned by co-operatives (95 per cent are privately owned). The big area where co-operatives flourish is not industry but retail trade of all kinds. The co-operatives have often sided with private enterprise against the government on questions of nationalization.

Communism has a relatively small following in Sweden. For instance, although the Social Democrats often found themselves in alliance with the Communists against a Conservative-Liberal coalition in parliament and in the Stockholm town council, they published very strong anticommunist literature in their last election campaign. The Communists lost quite heavily in this last election. There is no loyalty probe directed at Communists in Sweden of the type inspired by Senator Joseph R. McCarthy. As a matter of fact, several people well known to be Communists, are employed (as machinists and woodworkers) at the Aeronautical Research Institute where secret work is done for the Swedish Air Force.

The official Swedish policy is still neutrality but a good many people wonder if it will be possible to remain neutral if war should come. Military preparedness is on a high level and the feeling seems to be that Sweden would fight any invasion of her territory. Sympathies are almost entirely with the West but it does not seem that the people are ready to join in any military alliance such as the North Atlantic Pact.

Internationally, Sweden is as always, officially neutral, but almost all of the people are openly opposed to Communism and Russia. In the Finnish winter war of 1939, many Swedish people volunteered and went to Finland to fight the Russians. Nowadays public opin-

(*Continued on page 212*)

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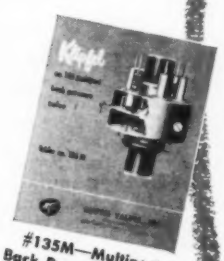

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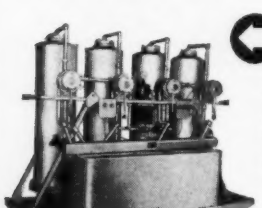

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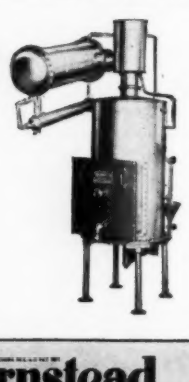

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STUDY IN SWEDEN

(*Continued from page 210*)

ion is probably more firmly set against the Russians than it was then. The press presents the news more impartially than does much of the American press but is strongly inclined toward the West. In recent months the Russians have not helped to promote friendship either. Since August there have been four incidents. Three of them involved alleged detention of a Lithuanian citizen by the Swedish authorities. Pravda and the Moscow radio have also begun to accuse Sweden of being unneutral and of being a tool of the Americans.

Recently one of the picture magazines came out with an article headed "*Res Hem Hr Laritchev*" ("Go Home Mr. Laritchev" – the Russian Naval attaché who was accused of spying). The article listed eight incidents since 1945 when members of the Russian Embassy were accused of spying. Other anti-Russian sentiments, although milder, have been expressed by almost everyone Mr. Randall has met. Many fear war in the near future; most feel that Sweden will be unable to keep out.

Swedish View of America

The Swedish people as a whole have a better picture of America and American life than do many other Europeans. Throughout Sweden one finds that many people have relatives in the United States with whom they are in fairly close contact. Through letters and visits they have been given a truer view of our life than is furnished by the movies. Though American films are widely circulated, the fantastic is recognized as such and not accepted as the truth. The newspapers devote considerable space to American news and descriptive articles. In one paper now, there is appearing a series of articles on television in the United States. There was a two- or three-page story recently in another paper about life in New York City. A full column, a few weeks ago, was devoted to Senator Robert A. Taft's campaign for re-election. These articles are furnished by Swedish correspondents in the United States or by co-operation with American newspapers. One good feature of the newspapers in the summer is that they all have a column of news in English – one column in one newspaper was complete with baseball scores and standings.

Mr. Randall reports that the people he has met have all been genuinely interested in the United States. All kinds of questions are put forward, and anyone coming to Sweden needs to have a full knowledge of our resources, geography, Constitution, the rights of the individual, social legislation, the operation of the Marshall Plan, our customs, and the general operation and attitude of our country and its people. An American is assumed automatically to know almost everything about America, and it has been difficult at times to come up with a good answer to some of the questions asked.

A strange fact to many is that in America one can move around the country at will and without having to tell anyone. That a foreigner is also quite free is even more astounding. In Sweden the citizens are reg-

istered both with the government and with the church (state controlled), and when they move to another town they must notify the authorities. A foreigner must register with the police everywhere he goes.

Swedish Students at M.I.T.

The M.I.T. Foreign Student Summer Project is widely known throughout university circles in Sweden. From the point of view of the Swedish students it has but one fault: that is the fact that only three Swedish students can come over to M.I.T. each summer. This has led to strenuous competition for the opportunities available. Those who have returned to Sweden from M.I.T. have written several articles about their experiences in the school newspapers, and this has no doubt helped stimulate interest.

Some Swedish students have inquired about the possibility of coming to America for a short while to do research work with a private company. Many of the young engineers are not as interested in further study as they are in getting a glimpse of the United States and American industry. They would like to do research work or other work of an instructive nature where they could observe the industrial techniques, production methods, and the other reasons that give American industry a high productivity. Such exchange occurs between various European countries.

Foreign Study and Research in Sweden

The Americans who come to Sweden are highly appreciated, both for the work they do and for the contact with America that is made through them. To say that one is from M.I.T. is to find an esteemed welcome and open door.

The M.I.T. students who spent the summer in Sweden believe there are many other possible opportunities for study in Sweden. A man interested in electric power problems, for example, should find advantages to study in that country. Sweden has always been interested in the generation of electric power and its transmission. A group of Swedish electrical engineers who returned recently from a trip to the United States expressed the opinion that Swedish engineering was equal to that found in America. Students of marine engineering should also be able to benefit from study in Sweden as it is one of the leading ship-building nations and has pioneered many innovations. Public health, biology, and paper chemistry might also offer unusual research possibilities.

In conclusion the visitors from M.I.T. believe that their summer experience was extremely valuable. In their professional fields they have learned to look at a number of problems from different points of view than the ones to which they were accustomed. They became acquainted with theoretical and experimental methods of attack entirely new to them. In some cases they were able to work outside their specialized fields at M.I.T. But above all they felt that they had become acquainted with a different way of life, and had learned how America is regarded from the outside. They believe that now they have a much better understanding of the problems involved in achieving a brotherhood of nations.

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OPERATIONS RESEARCH

(Continued from page 194)

which are in short supply. The whole problem of planning a combined production, storage, and sales operation involves many aspects of probability and game theory, and usually requires a sequence of hypothesis and trial before it is possible to design the operation so as to be most efficient.

An interesting example of an application of game theory turned up in the analysis of the ability of our strategic bombing airplanes to survive attack by enemy jet fighters. This analysis was carried out last year by the operations research group attached to the Joint Chiefs of Staff. Data from all possible sources were used. Data on vulnerability of airplanes were combined with data on accuracy of fire for various assumed tactics of the fighter and bomber, to obtain the probability that the bomber would be shot down on a single pass of the fighter against it. Calculations were made for a variety of altitudes and speeds, for different angles of approach of the fighter, and for different armament. In some cases, for example, when the bomber fires back at the fighter, there is a chance that the fighter will be destroyed before its own shots take effect. The effect of this probability on the outcome of the duel was included in the studies, using the techniques of game theory.

As the study went forward, certain optimum tactics for both fighter and bomber became apparent. These tactics were then checked against actual tactics employed as a continuing check on the realism of the calculations. In addition, the probable results of bomber-fighter duels for World War II conditions were also worked out and were checked against World War II data. We now have data from both sides on German–United States bomber-fighter duels in World War II. The comparison of our calculations with these data shows how important it is to take all aspects of the problem into account before the final result is arrived at.

The first theoretical results of our calculations of the duel between the *B-17* and the German fighter were of course equivalent to results which could be obtained in proving-ground runs, with none of the complications of actual combat involved. Probabilities of about 45 per cent that the bomber would be shot down in one pass of the fighter against it were given. The gunfire accuracies used checked the very voluminous German gun-camera data, which we have obtained on this type of duel. However, the same German data showed that operational results in actual combat gave a markedly different picture from proving-ground results, in that gross errors were present. In many passes by the fighter, the aim never steadied on the bomber at all. Because of nervousness of the fighter pilot or other influences, many runs occurred in acutal combat where the fighter guns never actually got pointed at the bomber, and the shots fired were wasted. In fact, according to the German battle data, in only one-third of the passes by German fighters did the gun sights actually steady on the bomber target. In these cases, the proving-ground results, predicted by the calculations, turned out to hold for

(Continued on page 216)

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OPERATIONS RESEARCH

(*Continued from page 214*)

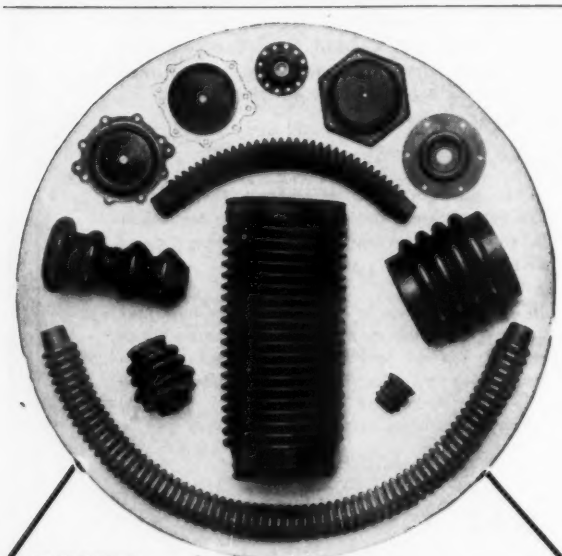
actual combat with about the predicted accuracy and the predicted losses per pass. In the other two-thirds of the cases, practically no hits were obtained and the runs were a complete loss as far as the fighter was concerned. Consequently in the case of World War II bomber-fighter duels, the operational figures on the probability of shooting down the bomber by a fighter in a single pass turned out to be one-third of the proving-ground results.

Thus corrected for gross errors, our theoretical calculations predicted approximately a 15 per cent probability of shooting down the *B-17* on a single pass by a German fighter, which checked remarkably well with actual data on the air battle over Germany. Such a detailed check with operational results for World War II gave us confidence in our predictions on future battles as long as we took into account the operational, gross-error factor which must be added to theoretical proving-ground results. It also showed that reduction of gross errors, by training perhaps, would pay off at least twice as well as reduction of gun-sight errors.

Career Opportunities

Perhaps enough has been said by now to indicate that operations research is a field of applied science with career possibilities for scientists and engineers having an interest in applying their scientific training and research ability to practical affairs. More examples have been given of its successes in military operations than in other fields because the writer's experience has been largely in this field and also because, in the present state of the world, the military applications are of crucial importance. There are a number of interesting developments in nonmilitary applications, however. A Committee on Operations Research has recently been set up in the National Research Council to foster training in this field and to help extend activities to other governmental and commercial activities. A well-known firm of industrial consultants is already successfully applying the techniques to business and industry. Enough has been done to show the opportunities for successful careers.

But at present the military applications loom largest. Each of the services has recognized the great importance of the technique. There are now five operations research groups devoting full time to military problems: the Operations Evaluation Group of the Navy; the Operations Analysis Section and Project



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Rand, both working for the Air Force; the Operations Research Office of the Army; and the Weapons Systems Evaluation Group, attached to the Office of the Secretary of Defense and to the Joint Chiefs of Staff. Each of these groups is attached to a high echelon in the military staff. Each has scientists in Washington and in the field where military action is taking place (in Korea, for example), working on problems of fundamental importance. Each group is in urgent need of more scientists to carry out its increased responsibilities. Any scientist or engineer who is considering volunteering to help in the present emergency would do well to consider these opportunities for service.

If we are to survive in this present world, the free nations must make brains take the place of more men. Man power has always been valued more highly by occidental nations than has been the case in oriental countries and, by their very nature, democracies cannot be blind to the loss of their man power. Of equal importance, of course, is the husbanding of other resources of the nation, and the exercise of care that in time of real need these are used most efficiently and with greatest effectiveness against our enemies. Operations research provides an opportunity for scientists to contribute to a more effective use of our resources of men and material, while at the same time carrying on research of scientific importance in applied science. The study of operations research has the further advantage of offering career opportunities in industry, either in war or in peace, which could have pronounced influence on the management of industrial operations.

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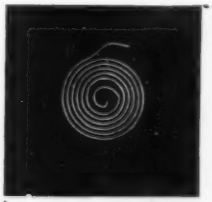

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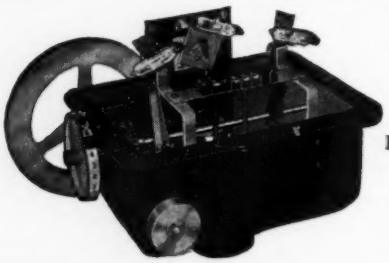

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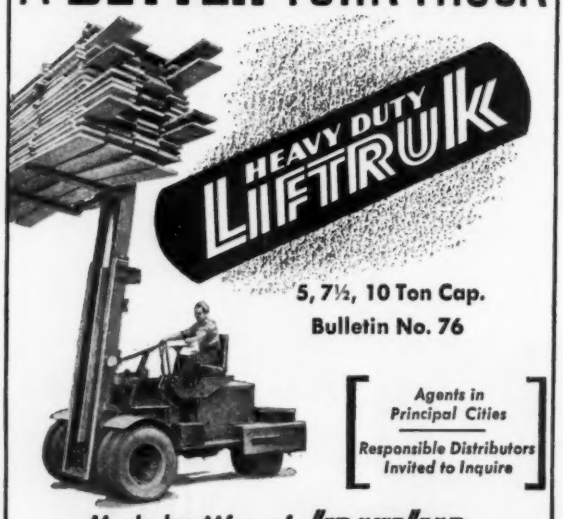

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AUTOMOBILE SAFETY

(*Concluded from page 196*)

makes his chances of survival very much less. This applies both to the front, and rear seats, and many casualties result when rear-seat cushions and springs jump from their moorings and inflict serious injury upon occupants. Harper points out that proper seat fastenings are not difficult to engineer. It is simply that nothing has been done to change their design and make them less dangerous.

Automobile door fastenings are similarly at fault. Well over half the deaths and injuries to front-seat passengers result when the person is thrown into the street – there to be crushed by passing traffic or killed by fracture of the skull. Harper believes that removal of this danger is simply a matter of designing proper door fastenings so that they will withstand a side thrust of at least 10G.

Harper cites thousands of accidents caused when cars go into spins as the result of sideswiping or oblique collision. A large proportion of these mishaps are initiated by ornamental bumper guards, which readily hook each other and set up violent skids. The same thing is true of fenders which break the smooth line of the automobile body. All cars, according to Harper, should be completely smooth on the outside, with recessed bumper guards, fenders faired into the body, and even sunken door handles.

Harper sees no hope for the pedestrian until traffic laws governing him become more stringent. Pedestrians do not realize that the momentum of a car weighing 3,500 pounds, which is traveling at 25 miles per hour, is over 70,000 foot-pounds, or that its probable stopping distance, allowing for a one-second delay for the driver to react, is nearly 80 feet. Thus, people step into the street assuming that an oncoming car can always stop. The situation is made worse in many cities where pedestrians have the right of way the moment they step onto crosswalks. The result is a steady toll of death and injury. The only cure for it, in Harper's opinion, is the traffic light; or, where that is not practicable, the substitution of the principle that pedestrians must cross streets at their own risk.

One important improvement in pedestrian protection, Harper believes, would be to outlaw the ornaments which today adorn almost every make of car. Especially deadly are the sharp-pointed radiator gadgets that give the driver a sense of power and swift freedom. Many of these resemble artillery shells and tomahawks. But when a pedestrian is struck and thrown onto the hood of the car, the ornament very frequently turns injury into death by disemboweling him. Children are particularly endangered by ornaments, since these are at the level of their heads. Many a child has had his skull split open by the equivalent of a 20-millimeter shell traveling with many times the momentum of an actual shell fired from a gun.

Harper looks forward to the day when public demand will bring about the few minor engineering changes that will make cars relatively safe for riders and for pedestrians. The amazing thing is, he points out, that the automobile industry has reached the half-century mark without appreciating the importance of applying simple physical laws to control accidents.

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EDUCATION FOR FREEDOM

(*Continued from page 195*)

The most elaborate and complete college catalogue is no guarantee that education will be the product of four years of attendance. Education is not something which is imparted to a student by an instructor. It is something which happens within the student himself in response to his own efforts. Lest someone should now jump to the conclusion that professors are superfluous, the writer hastens to add that the function of the instructor is inspirational.

Education, therefore, is a product of a relation between the student and other individuals. The high purpose of the university or college is to provide the intellectual environment which will inspire the student to the effort toward education. The environment must include, of course, professors: but the professors should be more than teachers from textbooks. They should be — whether scientists, engineers, or philosophers — men who in themselves exemplify the spirit of free inquiry and the sense of responsibility.

The school has another duty of comparable importance. Even a college professor must admit, however reluctantly, that much of the inspiration the student finds at college comes from his fellow students. In the good college, the desire for education wells up from within the student body itself. It would seem, therefore, that the college must select its student body with a care commensurate with that it uses in selecting its staff. By this I do not mean that the freshman class should consist only of the more erudite or the socially more fortunate youth of the country. On the contrary, it should be a cross section of that fraction of our youth who are intellectually most alive. It should not be narrow in the range of its interests.

This is a weakness in the educational climate of M.I.T. We have tended to draw our students from too narrow a range of interests — an unnecessarily narrow range. A general education built around a scientific core should appeal strongly to the youth of today, whether or not he is headed for a career in science or technology. Moreover, the vocational or professional element which is traditional at M.I.T. is of great value as motivation of the student in his quest for an education. As these considerations become clearer, the educational climate at M.I.T. will become more favorable.

The concept of education in a free society which is outlined here may be summarized as the fullest pos-

(*Concluded on page 222*)

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EDUCATION FOR FREEDOM

(*Concluded from page 220*)

sible intellectual development of the individual. In one sense this is a proposal for exploration, in that even in the democratic countries this objective is still a very remote one. Nevertheless, it has been the tacit objective of the American tradition in education. It has come down to us through Emerson, Thoreau, and William James. More recently it has been referred to by John Erskine as "the moral obligation to be intelligent." We find it in the words of Alfred North Whitehead: "where attainable knowledge would have changed the issue, ignorance has the guilt of vice." And, again, from Mark Van Doren: "democracy depends for its life upon the chance that every man will make all the judgments he can . . . democracy's only authority is reason, its only strength criticism."

It is fitting to conclude with the words of a great contemporary spokesman for the American tradition in education, John Dewey: *"Fidelity to the nature to which we belong, as parts however weak, demands that we cherish our desires and ideals until we have converted them into intelligence, revised them in terms of the ways and means that nature makes possible. When we have used our thought to its utmost and have thrown into the moving unbalanced balance of things our puny strength, we know that though the universe slay us still we may trust, for our lot is one with whatever is good in existence. We know that such thought and effort is one condition of the coming into existence of the better. As far as we are concerned it is the only condition, for it alone is in our power. . . . To ask in good faith as much as this from ourselves is to stir into motion every capacity of imagination, and to exact from action every skill and bravery."

**John Dewey, Philosopher of Science and Freedom;* a symposium edited by Sidney Hook, page 37 (New York: The Dial Press, 1950), $3.50.

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We should accept this responsibility, not through fear, but because we are men enough, American enough, to recognize and face grim reality, and deal with the problem of safeguarding our families and our neighbors.

Utica, New York
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American Association for the Advancement of Science
Cleveland, Ohio
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American Chemical Society
Los Angeles, California
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American Society of Agricultural Engineers
Chicago, Illinois
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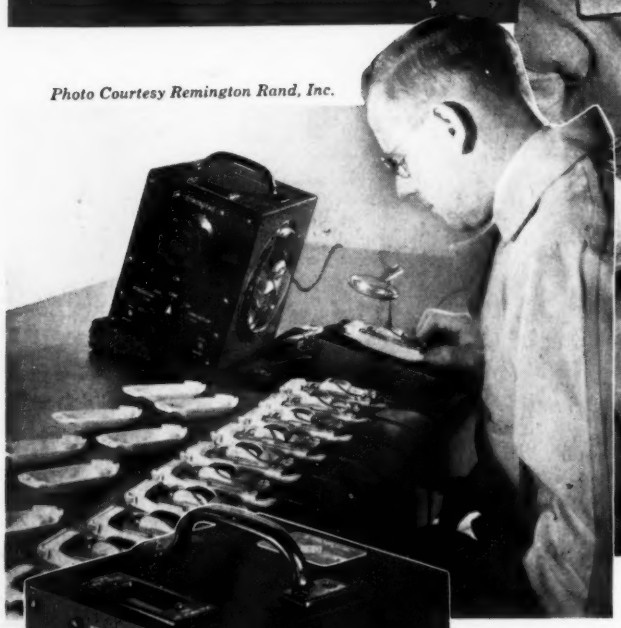

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